Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

NOVEMBER 1958

A McGRAW-HILL PUBLICATION

60 CENTS

Team Report on Control Inside RUSSIA

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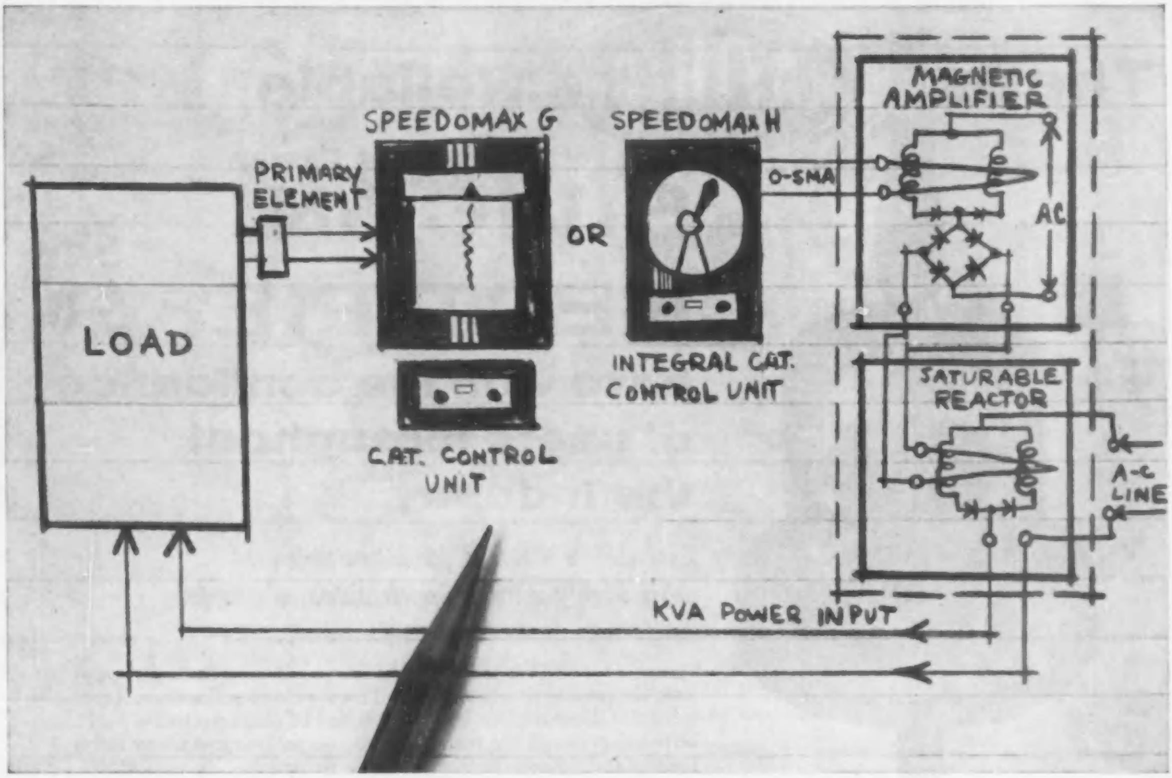

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Control ENGINEERING

NOVEMBER 1958

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page

Control ENGINEERING

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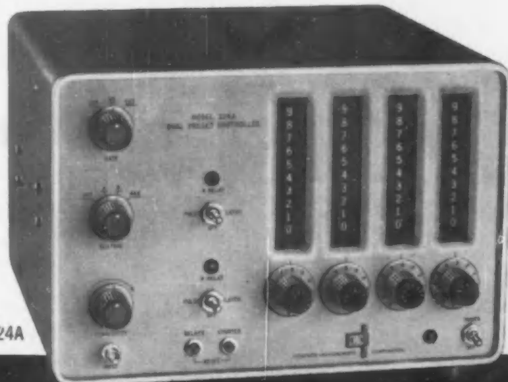

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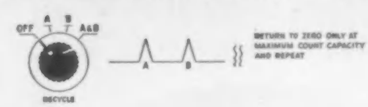
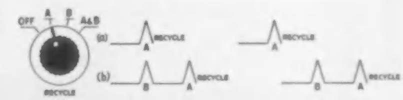
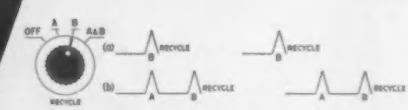


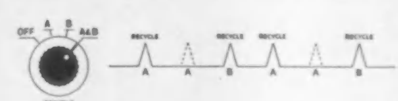
1. With RECYCLE switch in the OFF position, output information is obtained at both the first and second preset selections but the counter continues to totalize, until the maximum count capacity of the instrument is reached. The counter then resets to zero and repeats the cycle as above.



2. With RECYCLE switch in the A position, (a) output information is obtained from the A channel and the instrument recycles on A. (b) If the B channel selected number is less than the A channel number, the unit will provide output information at B and continue on to the A channel selection as above.



3. With RECYCLE switch in the B position, (a) output information is obtained from the B channel and the instrument recycles on B. (b) If the A channel selected number is less than the B channel number, the unit provides output information at A and continues on to the B channel selection as above.



4. With RECYCLE switch in the A & B position, the instrument provides output information and recycles alternately on the A & B channels. For example, when the unit is recycling on A, B is ignored and when recycling on B, A is ignored. This position is ideal for generating a chain of variable spaced pulses.

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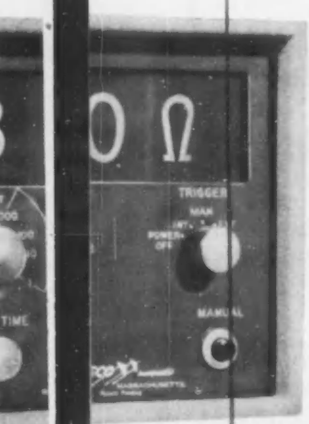

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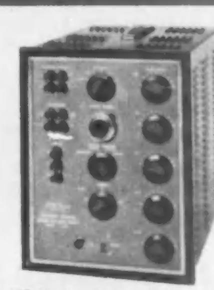

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SHOPTALK

Stop the presses

Normally, publishing a monthly magazine is a pretty methodical process, but every once in a while something turns up that completely upsets the applecart, making the editors suddenly feel that they're working on a weekly or even a daily publishing schedule. For months we'd been planning to bring you the special insert covering the benefits of modernization through instrumentation and automatic control in this, the November, issue (see previous *Shoptalks*), and a report on electronic process control systems in December. But then Editor Bill Vannah and his team returned from Russia loaded with info on the status of Russian control. We didn't have any space until December, but the information had to be presented immediately. The question: what to do?

The team comes through

There was only one solution: push off the modernization insert to December and run special reports on control inside Russia and electronic process control systems in November. By special delivery, telegram, and phone, team-leader Vannah obtained the reports of the other team members (a task that could only be accomplished with their complete cooperation), organized his own copious notes, and prepared the comprehensive look at Russian control starting on page 65.

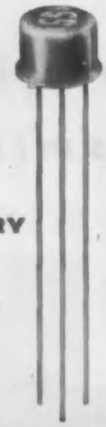
He could have worked all night

But what of the article by Associate Editor Harry Karp on electronic process control systems, originally scheduled for December? Informed of the change on a Friday night, Harry worked Saturday, Sunday, and until the wee hours on Monday and Tuesday nights to add the finishing touches. He was just about done when L&N announced that it, too, had a new system. Here Harry gets the low-down from L&N's F. H. Chan.

Incidentally: the pages of the Vannah and Karp articles are perforated; take them out and file them.

Control computers show up

Two September exhibitions—the ISA show in Philadelphia and steel show in Pittsburgh—demonstrated that both control makers and users feel the process control computer is rapidly gaining acceptance (see *What's New*, pages 18 and 38). This is a switch from a year ago when only two or three makers and CtE preached the practicality of computing control.



NEW FROM SPERRY

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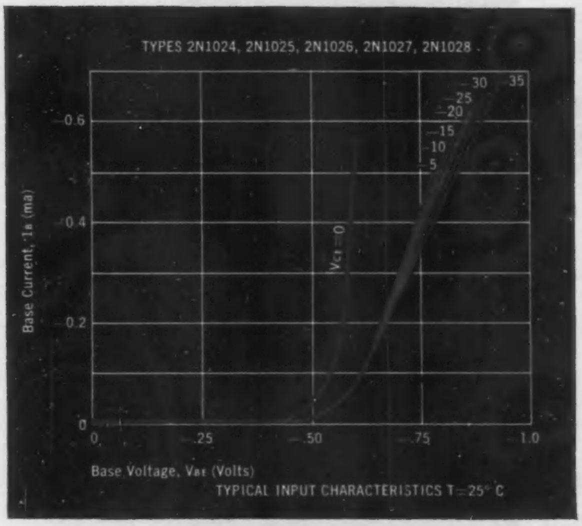

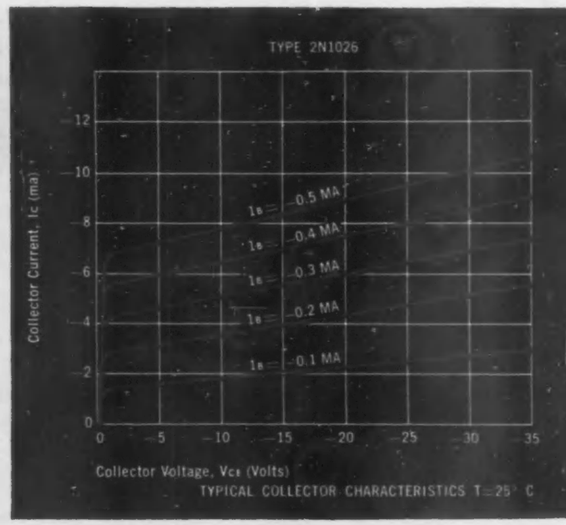

SPECIFICATIONS				
TYPE	COLLECTOR VOLTAGE	BETA	[illegible]	APPLICATIONS
2N1024 2N1025 2N1026	[illegible]	[illegible]	[illegible]	[illegible]
2N1027	[illegible]	[illegible]	[illegible]	[illegible]
2N1028	10v	9 min.	[illegible]	High speed computer switching

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Rightfully puffs chest

TO THE EDITOR—

We were extremely interested and pleased in the article in the June issue of CONTROL ENGINEERING regarding instrumentation at Cape Canaveral. In particular, we are pleased to note that the Giannini Co. was mentioned as one of the pioneers in digital data recording for radar equipments. As a matter of record, the equipment being used at Patrick was designed in the fall of 1952.

You also mention the improved transistorized module which permits data to be recorded in a single punched tape with excellent reliability. Since it is not clear from your article, it should be mentioned that this improved model was also designed and manufactured by the Datex Div. of the Giannini Co. The improvements were made possible by the operating experience gathered by AFMTC personnel, by the availability of reliable transistors at reasonable cost, and by the use of the new high speed tape punch manufactured by the Teletype Corp.

Carl P. Spaulding, President,
Datex Corp.
Monrovia, Calif.

Thank you. Next? Ed.

Wants more on A-warehousing

TO THE EDITOR—

In the June 1958 issue of CONTROL ENGINEERING (page 73, *Industry's Pulse*), you refer to a number of articles relating to "the automatic warehouse".

Particular reference is made to an IBM system developed for a soap and drug manufacturer. Would you please advise where information on this system was published, or if you have a reprint of the pertinent article, please send me a copy and bill us accordingly.

We would also appreciate any other information you may be able to point out in connection with automatic warehouses.

M. Hoffman
Designers for Industry, Inc.
Cleveland, Ohio

The mention of the IBM system was picked up on a trip and verified with IBM. Nothing has been published other than this mention. For information on other automatic warehouses, see CtE, Mar., p. 20, and June, p. 21. We will publish a technical article on automatic warehousing in January or February. Ed.

Alexander M. Letov

a Russian thrives on control theory

At the Automatics & Telemechanics Institute of the Academy of Science in Moscow, Russian control engineers and scientists study the theory of automatic and remote control, and apply the results of these theoretical studies to industrial problems. As deputy-chief editor of the magazine, *Automatics and Telemechanics*, the institute's deputy director, Alexander Letov, reviews the broad field of Soviet control technology. And as one of the Soviet's outstanding theoreticians in the control field, Professor Doctor Letov continues to make significant contributions in control systems research.

The 47-year-old Letov is good example of what the Soviet education system produces. He was selected to attend the University of Moscow, finishing work under the Mechanical & Mathematical Faculty in 1937. He specialized in applied mechanics, majored under Professor Bulgakov. Upon graduation, Letov received no degree, though he was given the title, *Scientific Worker & Teacher of Mathematics & Physics for High School & Colleges*, vividly demonstrating the Russian fondness for long, impressive titles.

After graduation, he was assigned to the Scientific Research Institute in Moscow, where he concentrated on the theoretical aspects of gyroscope movement. During World War II, he was transferred to a manufacturing plant, one that built instruments and automatic control equipment; here Letov served as a test engineer. While Letov worked at the instrument plant, Bulgakov, his professor at the university, suggested a number of problems for Letov to solve for the thesis which is required before a Russian college graduate receives his first official degree—the degree of candidate (equivalent to the master's degree in the U.S.).

Letov attacked these problems as part of his work at the plant. His thesis, "Theoretical Aspects of the Autopilot", was completed in 1945 (published in 1946), and earned for him the degree of *Candidate of Physical & Mathematical Science*.

Despite his war-time exposure to practical control problems, Letov still preferred theoretical work. Even today, he shuns discussions on the use or design of hardware.

After the war, Letov returned to the Scientific Research Institute and switched his studies to nonlinear control systems. He carried on the work of the Russian scientist Lapunov, who had developed a method of investigating control system stability by using a differential function. But he (Lapunov) had never developed anything on how to construct these functions. By 1949, Letov had written a doctoral dissertation describing methods of constructing Lapunov functions. He successfully defended his dissertation in 1950 and it was published as a book shortly thereafter. For this he was awarded the degree of *Professor Doctor of Physics & Mathematical Sciences*. Princeton Press is currently translating the book and will publish it early next year.

By 1956, Letov had moved to the Automatics & Telemechanics Institute, changing his area of work slightly. Now he is working on a book that discusses optimum control system time transients. He expects it to be finished by early 1959. Whether it will be published or not depends on how the manuscript survives the tough Soviet screening process. The manuscript will be sent by the publisher to a number of experts in the field. Their identities are kept secret so that Letov cannot influence them. Before the book is approved for publication, says Letov, two of these "opponents" must accept the views expressed in it. If not, the manuscript goes unpublished.

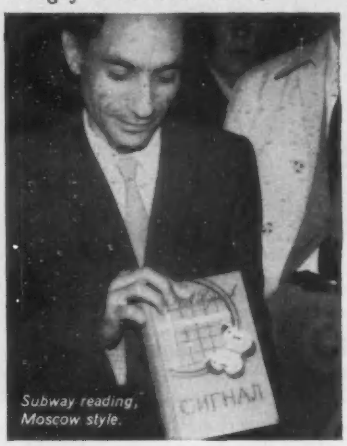
In Moscow, Letov leads a top scientist's luxurious life, the special compensation offered by a grateful government. With his family—his wife, a daughter Tanya, 18, and a son Dima (short for Demetri), 9—he occupies a two-room apartment on the 17th floor of a brand-new 25-story building. His apartment house is just a 10-minute drive over Moscow's sparsely trafficked streets from the institute; Letov

RAMBLINGS ON INSTRUMENTATION

The Mysterious East

(It's-a-Small-World Division)

(Mr. Sprague and beard have recently returned from a visit to the U.S.S.R. with the Automatic Control Delegation. Herewith, some ramblings from the borscht circuit.)



Subway reading, Moscow style.

The other day, when a group of us were on the way to the Hotel Ukraine via the Moscow subway, we ran into a serious type pouring over a volume 'midst the swaying bodies. Intrigued by his concentration, we asked through our interpreter, what he was reading. The reply: a book on Automatic Control and Cybernetics. Knowing that no one would believe us, we snapped the above photo.

Seriously, this incident symbolizes the intentness with which the Soviet appears to be focusing on the theory and application of instrumentation and control devices. It was my impression that their technology is moving rapidly and is not a "house of cards"; rather it is soundly based on rigorous training in theory and application, as well as continuing emphasis on the fundamental standards which are the cornerstone of all science.

While ours was but a fleeting (and Soviet-selected) glance at an enormous country, I got the impression that—borrowing heavily from German and American designs—the Russians have built an instrument and control industry which, with a few old Lend Lease exceptions, is supplying their plant requirements.

It would appear that the focus will continue to be on producing relatively standard instruments in large quantities to meet the tremendous demand created by their 5-year plans for rapid industrialization of the country. We were told that they anticipate the instrument and control industry to increase 2.8 times between 1956 and 1960.

But we got more than a hint of their relatively new interest in foreign markets. China, Czechoslovakia, India, Argentina and 26 other countries were mentioned. Using their hole cards of, (a) concentrating large volume production of a single item in a single plant and, therefore, achieving rapidly decreasing costs and, (b) arbitrary manipulation of their exchange rates, the U.S.S.R. can be expected to be a rugged competitor on the international automation scene very soon.

Should we shudder? *No*, but I do think we should supplement the drive or motivation (which has become rather jaded of late) toward conspicuous consumption of washers, dryers, TV sets, et al, with a more individual concern for the care and feeding of our human resources. Let's face it—this is a Brains Battle and we can work out solutions for the development—*our way*—of our people of talent only if we realize it is necessary.

And, on the international competition issue, let's do more of what comes naturally; i.e. continually obsoleting products by innovation and improvement . . . constantly posing "this model is better" choices for customers here and abroad, as (commercial plug) we are trying to do here at Hays with, for example, *this year's* new products: the Universal Recorder, the new 245 flow transmitter, the 913 BTU Recorder and a new approach to gas sampling systems. So let's over-estimate the competition and rediscover our greatness.

Phil Sprague Jr. President

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LETOV . . . Soviet Theoretician

likes to do the driving himself. For summer living, he has a *dacha* (summer home) about 40 kilometers from his apartment.

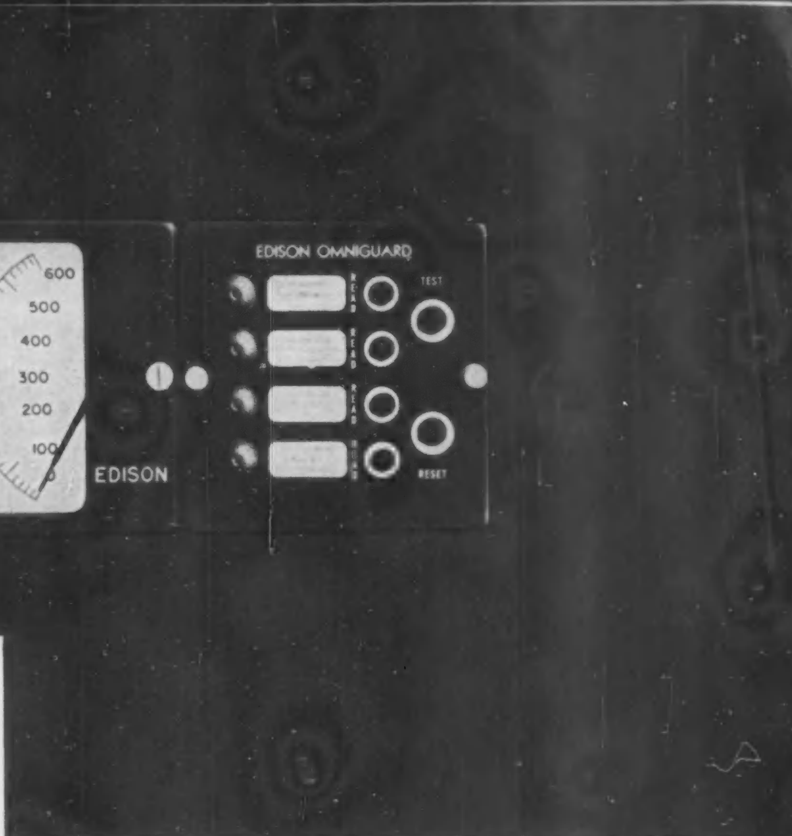
The wiry control engineer is an ardent sports enthusiast, prefers participating to watching. In the summer, his favorite diversion is swimming—in a pool in Moscow, or in the Moscow River when he's visiting his *dacha*. In the winter, he goes skiing at his *dacha* every Sunday.

On first meeting the steely-eyed, grey haired Letov, one gets an impression of cold reserve. Part of this probably can be traced to traditional Russian distrust of strangers; part is undoubtedly Letov's lack of familiarity with the English language—he can speak it, and read it, but he has difficulty understanding conversational English. However, once his initial reserve is swept away, the Soviet scientist proves he has a keen sense of humor and a warm personality.

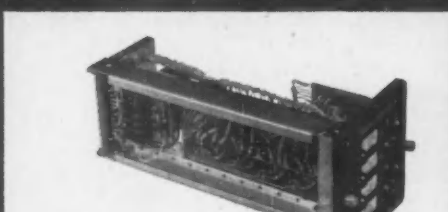
During a sightseeing trip in New York City, Letov sported this human side. At the famous Cathedral Church of St. John the Divine, he listened intently to a guide's description of plans for additions to the church. When he heard that two towers were to be added, one named for St. Peter and the other for St. Paul, Letov with a sparkle in his eyes looked at a Russian associate. "Just like him," he said pointing, "He's Peter Paul—but no saint!"

In September, Letov came to the United States to attend the ISA Show in Philadelphia. It was his second visit to this country. His first trip had been to the AIEE meeting in Atlantic City in October 1957. His first-hand looks at U.S. control technology led him to conclude that Soviet and U.S. control theory is about on a par, but that there are certain areas in which the Soviets have concentrated more heavily than have U.S. control specialists. Typical examples of Soviet emphasis: the theoretical aspects of control system stability; application of random functions to control system theory. The U.S., says Letov, has put a heavier emphasis on some areas, too. One example: dynamic programming, the solving of function equations which describe processes in dynamic systems.

For the future, Letov predicts an even greater importance for automatic control techniques in industrial applications. He sees, for example, a great potential for digital computers in process control. And he hopes to speed their use in the Soviet Union by continuing his theoretical studies.



Model 310 Edison Omniguard with Model 311 Indicator—a single indicator can read any number of temperature points.



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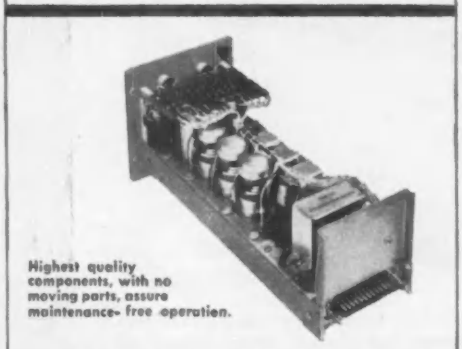

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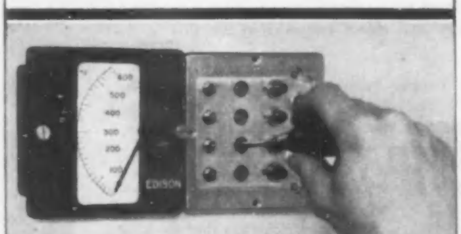

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3. **DEPENDABLE:** Rugged design with highest quality components, no fragile moving parts.
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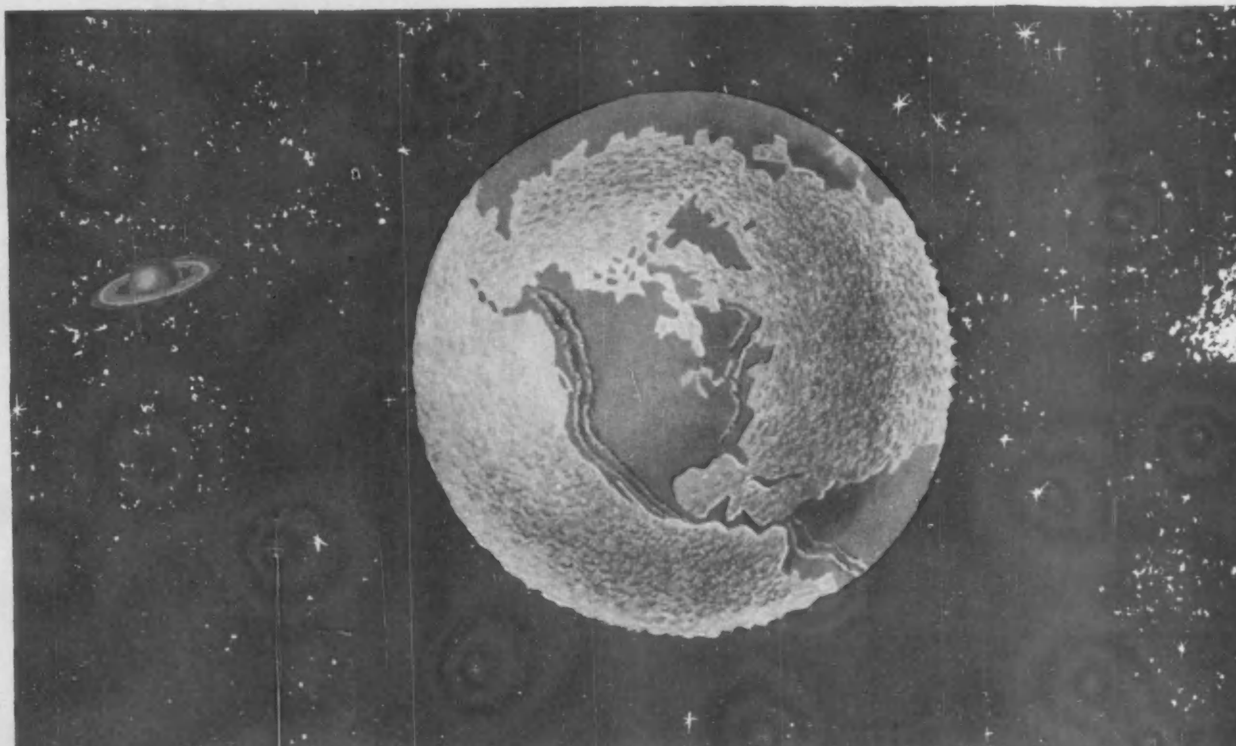
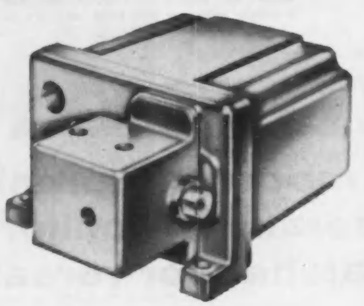
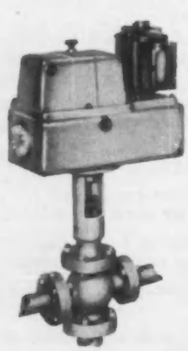






Above, left—The GPE Controls Electric Flow Transmitter, a completely new idea in flow signal transmission. Completely transistorized, without complex mechanics, it transmits a high-level signal proportional either to flow or to differential pressure. Precise measurement and signal transmission are first in importance in good control.

Above—The Libratrol-500 Process Control System, made by Librascope and available to industry through GPE Controls, Inc., is developed around this highly reliable, rapid-response digital computer. It provides for a full range of process control—from accurate processing of data to provide understandable information to a human operator, to complete automatic control of an entire process or group of interrelated processes.

Left—One of many GPE Controls Electrohydraulic Valve Actuators that combine the speed and positive action of hydraulic valve operation with the flexibility of electrical control and signal transmission.

Engineers doffed their coats in turkish-bath temperatures of Philadelphia's Convention Hall. But the humid atmosphere failed to wilt their enthusiasm for displays of new electronic control systems. Shirt-sleeved visitors crowded continuously around The Foxboro Co.'s exhibit, for example, to see the unveiling of the solid-state, electronic Consotrol system.

New Role for Electronics in Process Control

Electronics steals the scene at 13th annual ISA show. New electronic control systems, computers for control, and electric actuators imply wider use of electronic devices. Altogether at the Philadelphia exhibition, makers turned out a record number of new products.

PHILADELPHIA—

After five years of almost making the grade, electronics has finally broken into the process industries in a big way. In Philadelphia's steamy conventional hall in September, visitors to the 1958 ISA Instrument-Automation Conference & Exhibit saw electronic control devices displayed on every side. And what was more, the users were animatedly talking electronics, too.

Having faced 12 months of recession, control makers appeared ready to heed the advice of those economists who have urged "new products to pull the country out of the business low". Apparently a lot of makers decided to break with tradition, reached into electronics for something really new.

What caught the king-sized share of attention in Philadelphia were these three areas: 1) electronic process control systems, 2) computers for control, and 3) electric actuators. All three seem to work together. Awed by the display, one user engineer tried to explain it this way: the new actuators must have been developed to go along with the new electronic control systems; and the new control systems were probably being pushed by the suddenly heated interest in computing-control.

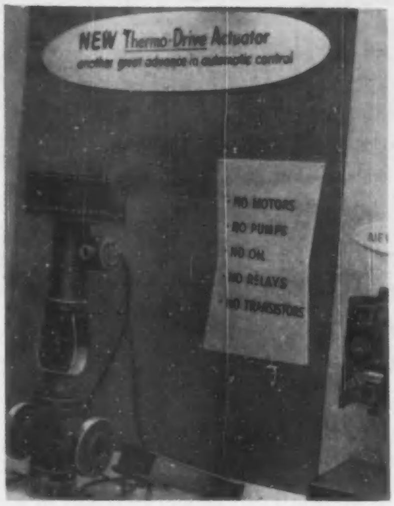
Electronic control has had tough sledding because none of the old-line suppliers of process control offered such equipment. For almost seven years only Swartwout and Manning, Maxwell & Moore made electronic systems. But at the show, four brand new systems were unveiled by companies that previously had promoted pneumatic systems heavily. They were Foxboro, Taylor Instrument, Minneapolis-Honeywell, and Leeds & Northrup.

Before the show it had been pretty well known that the first three companies would unveil new electronic systems. But the L&N display was completely unexpected. A surprised M-H vice-president said he found out about it only when he saw the display going up on the Friday before the show opened. For a complete description of all six systems, see the special report, "Electronic Process Control Systems", starting on page 81.

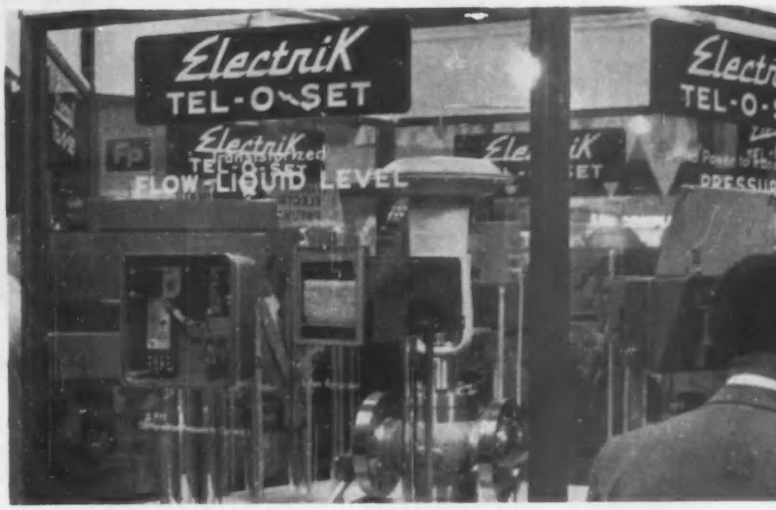
Nobody was predicting that electronic control systems would push pneumatics into obsolescence. Rather, there was a new awareness that each has its proper place in process control. Many of the new systems displayed would not be available before 1959.

Furthermore, all this activity seemed to be only a beginning. It was learned at the show that both Bailey Meter and Fischer & Porter have also developed electronic control systems, will announce them in the near future.

• **Computing-control is hot**—Along with electronic control, users were talking avidly about the potentials of computing-control. In fact, the receptive talk almost overwhelmed the already enthusiastic suppliers of such devices. A new concept of how to use computers in the process industries is rising.



Thermal-electric valve actuator displayed at Swartwout Co. booth was a show stopper. The five "No's" behind the device explained users' interest.



New Electrik Tel-O-Set system was the centerpiece of Minneapolis-Honeywell Regulator booth. Here's a closeup of flow liquid level control; pressure control is at right and valve actuator can be seen behind it.

Montgomery Phister Jr., director of engineering, Thompson-Ramo-Wooldridge Products Co., explained this new approach at an ISA show clinic on digital computers. Phister sees three echelons of computers in use. At the top is a giant data processing machine that will handle all of a process company's accounting, will schedule production based on orders received, inventory, and anticipated demand. It would send instructions to the second-echelon computer, whose job would be to control a complicated process such as a catalytic cracking unit in a refinery. For this work, Phister envisions a general-purpose computer, about the size and capacity of his company's RW-300.

For processes not as complicated, such as a fractionating tower, Phister sees a third-echelon computer. This may be either an analog or digital device. It will not have the capability nor cost as much as the second-echelon device.

• **Users concede**—At a technical session on computing-control, potential users made two big concessions. First, a control engineer from the petroleum industry said there was no doubt that manufacturers could now supply a computer reliable enough to serve as a controller in the process industries. Then a user from the chemical industries said there was no doubt that control engineers could supply the equations necessary to program a computer for control. The only question remaining, they agreed, was economic justification.

Meanwhile, on the floor of the show visitors could see several new developments in computing-control gear:

▶ The Libratrol 500 was displayed for the first time by GPE Controls. This machine is a modification of the Librascope LGP 30, redesigned to speed up arithmetic operations and to reduce access time. New input and output equipment has been added to the vacuum-tube, magnetic-drum device. An attractive feature: the price of $75,000 includes all input and output equipment (see page 129 for a full description).

▶ An incremental computer offered by Genesys Corp. uses a disc memory. This company has yet to sell one of its machines. A spokesman said that the price of the new computer, complete with input and output equipment, could run as low as $50,000 for a relatively simple computing-control job. Of course, the price would rise with an increase in complexity, and would depend, said Vice-president Geoffrey Post, on how much a company knew about the process to be controlled. If it has no idea of the mathematical equations defining the process, this company would have to first buy an experimental unit (around $100,000 for a single column) to determine the relationship of variables, then buy a computer specifically tailored to do the job for considerably less ($50,000). If the process were well known—and slow enough to permit economical use of the Genesys computer—the user could skip the experimental step.

▶ An analog computer for process control was shown by Southwestern Industrial Electronics Co. Com-

Digital Data Logger marked BJ Electronics' entrance into the industrial process field. Device works in conjunction with fm transducers which permit sending signals over long distances with little loss in accuracy.

Libratrol 500, general-purpose computer designed for process control, set tongues wagging with its low price tag—$75,000 with input and output equipment. Vacuum tube machine has a magnetic drum memory.

ISA Show story starts on page 18

Analog computer for process control was demonstrated by Southwestern Industrial Electronics. First installation is being used for open loop studies; but later computer may close the loop.

pletely solid state, the new device is accurate to within 1 percent. Sales Manager John Pink reported that the first installation has already started operation on a fractionating tower at Humble Oil's Baytown (Tex.) Refinery. On open-loop operation, it determines key variables in fractionator efficiency.

While touring the show, a visitor heard other plans for still more process control computers. Typical examples: Packard-Bell will modify its TRICE computer–a real-time device currently being used by the Army Ballistic Missile Agency to plot missile flights–for process control. IBM has designed a process control computer, will announce it before the first of the year. Philco and L&N are making progress on a joint design (CtE, Oct., p. 50).

At the Daystrom, Inc. booth, Systems Div. Manager Chalmer Jones reported that Daystrom's first operational information system–incorporating a general-purpose computer–had completed its first nine weeks at the Sterlington Station of Louisiana Power & Light Co. without a single difficulty or failure. This was more ammunition for computer-reliability pluggers.

Packard-Bell's plans and Genesys Corp.'s display have started process users thinking along a new channel in computers. Both of these machines are incremental devices; that is, they compute in steps, solving problems by integration. Inputs are increments instead of whole numbers, as in a general-purpose machine. The big advantage of such devices is cost. Their advocates point out that even a transistorized incremental computer can be built for much less than a vacuum-tube GP computer. Since user engineers now feel that economic justification may call the turn on computing control, this cost edge may give incremental devices an inside track.

In the electric actuator field, the new Thermo-drive device displayed by Swartwout (CtE, Oct., p. 117) caused exceptional interest. Some viewers termed it the most radical development in the process hardware field in years. In addition, it has this striking characteristic shared by all the other new actuators displayed: a compact design. The unit fits into a neat package that takes up little room.

• **New is the word**–With exhibitors throughout the show, the key word was new. A complete list of products displayed for the first time in Philadelphia would fill several pages. The new items ranged from computers to small hardware. Here are just a few of them:

▶ New paper-tape punch, displayed by Precision Specialties. It boasts a speed of 27 characters per sec; costs $295. An accompanying product is a new optical tape reader with speeds up to 1,000 characters per sec. It costs about $1,000, can be used with strips of tape only.

▶ Transistorized data processor and automatic data logger (Model 123), displayed by Systems Div. of Beckman Instruments. Big news about this machine is that it is standardized, can handle 80 percent of all data logging jobs with no modification. Another interesting fact: Beckman will rent it or sell it. Leasing is possible, say Beckman spokesmen, because of the standardization of design.

▶ Noncontacting thickness gage, called the Gammascan, introduced by Nuclear Systems Div. of the Budd Co. It can measure thickness deviations as small as 0.001 in. Major application: for control rather than indicating.

▶ Reference differential pressure transmitter capable of operating in wide ranges up to 5,000 psi, exhibited by International Resistance Co. This new unit, marking IRC's entrance into the instruments field, measures to ¼ percent accuracy. Biggest use is expected in military applications, particularly accurate differential measure-

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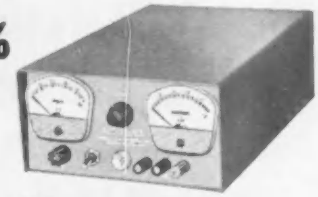
REGULATION and STABILITY 0.1%



Model SC-18-2-M

*Two units mounted in Rack Adapter RA-2

Model SC-18-4-M

* VOLTAGE REGULATED POWER SUPPLIES

MODEL	OUTPUT VOLTS DC	OUTPUT AMPERES DC	OUTPUT IMPEDANCE DC-1KC	OUTPUT IMPEDANCE 1KC-100KC	SIZE W	SIZE H	SIZE D
SC-18-0.5	0-18	0-0.5	.04	.4	8¼"	4 5/32"	13⅝"
SC-18-1	0-18	0-1	.02	.2	8¼"	4 5/32"	13⅝"
SC-18-2	0-18	0-2	.01	.1	8¼"	4 5/32"	13⅝"
SC-18-4	0-18	0-4	.005	.05	19"	3½"	13"
SC-36-0.5	0-36	0-0.5	.08	.8	8¼"	4 5/32"	13⅝"
SC-36-1	0-36	0-1	.04	.4	8¼"	4 5/32"	13⅝"
SC-36-2	0-36	0-2	.02	.2	19"	3½"	13"
SC-3672-0.5	36-72	0-0.5	.15	1.0	8¼"	4 5/32"	13⅝"
SC-3672-1	36-72	0-1	.08	.8	19"	3½"	13"

Patent Pending

(TUBELESS) TRANSISTORIZED

SHORT CIRCUIT PROTECTED

- **REGULATION:** 0.1% for line changes 105-125 volts at any output voltage in the range minimum to maximum.

  0.1% or 0.003 volt for load changes 0 to maximum (whichever is greater) at any output voltage in the range minimum to maximum.
- **RIPPLE:** 1 mv. RMS.
- **RECOVERY TIME:** 50 microseconds.
- **STABILITY:** (for 8 hours) 0.1% or 0.003 volt (whichever is greater).
- **AMBIENT OPERATING TEMPERATURE:** 50°C maximum. Over-temperature protection provided. Unit turns off when over-temperature occurs. Power-on-off switch on front panel resets unit.
- **TEMPERATURE COEFFICIENT:** Output voltage changes less than 0.05% per °C.
- **SHORT CIRCUIT PROTECTION:** No fuses, circuit breakers or relays! Designed to operate continuously into a short circuit. Returns instantly to operating voltage when overload is removed. Ideal for lighting lamps and charging capacitive loads.
- **OVER-CURRENT CONTROL:** Can be set from 0 to 120% of full load. Current is limited to preset value for any load including short circuit.

- **REMOTE PROGRAMMING** at 1000 ohms per volt is provided. Remote programming allows mounting a voltage control at a remote point.
- **REMOTE ERROR SIGNAL SENSING** is provided to maintain stated regulation directly at load.
- **CONSTANT CURRENT OPERATION:** These units can be set up for constant current operation without internal modification.
- **POWER REQUIREMENTS:** 105-125 volts, 50-65 cycles. 400 cycle units available.
- **OUTPUT TERMINATIONS:** DC terminals are clearly marked on the front panel. All terminals are isolated from the chassis. Either positive or negative terminal of each DC output may be grounded. A terminal is provided for connecting to the chassis. The DC terminals, the remote programming terminals and the remote error signal sensing terminals are brought out at the rear of the unit.
- **CONTROLS:** Power-on-off switch, one turn voltage control, on front panel. Over-current control on rear of unit. Ten turn voltage control available on special order.
- Continuously Variable Output Voltage. No voltage switching.
- Suitable for square wave pulsed loading.
- Either positive or negative can be grounded.
- Units can be series connected.
- High efficiency
- Low heat dissipation.
- Compact, light weight
- For bench or rack use.
- Color: Gray hammertone. (Special finishes available).

ORDERING INFORMATION:

Units without meters use model numbers indicated in table. To include meters add M to the Model No. (e.g. SC-18-1-M).

*Rack adapter for mounting any two 8¼" x 4 5/32" units is available. Model No. RA2 is 5¼" high 19" wide.

*Rack adapter for mounting any one 8¼" x 4 5/32" unit is available. Model No. RA3 is 5¼" high 19" wide.

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CIRCLE 17 ON READER-SERVICE CARD

ments under a high static head. Price: $500.

▶ New recorder-controller designed especially for computing-control, displayed by Bristol Co. It features a third pointer that is set from a computer signal to indicate the set-point calculated to be optimum.

▶ Digital data logger, previewed by BJ Electronics Div. of Borg-Warner. The 100-point machine is designed to put to work techniques B-J had perfected for the military.

• **Reports on Russia**—For those who stayed at the show until the very end there were two bonus sessions, introduced at the last minute. In one, four of six visiting Russian control engineers presented papers describing aspects of instrumentation in the Soviet Union. In the other, three members of the American Automatic Control Council discussed their Russian tour.

Speaking of Russian accomplishments in instruments were A. M. Petrovsky, specialist in information theory, who described a new utility telemetry system using delta modulation; A. M. Letov, deputy director of the Institute of Automatics & Telemechanics, who described a mathematical technique for determining stability of nonlinear systems; A. B. Chelustkin, a specialist on steel instrumentation and control, who discussed gaging systems for the steel industry; and B. N. Naumov, who reported results of analytical work in computing-control. Naumov said the Russians are now ready to set specifications for a computer but had not yet chosen a process to control.

Reporting first-hand on some of what they saw in the Soviet Union were W. E. Vannah, editor of CONTROL ENGINEERING, N. Cohn, Leeds & Northrup Co., and P. S. Sprague, Hays Corp. Vannah, who headed the 13-man AACC delegation, started the session by reviewing the itinerary of the group. Cohn followed with a description of instrumentation systems the group had seen in actual use or in industrial exhibits. Sprague discussed some of the aspects of Russian instrument plant management. (For a more complete report, turn to page 65.)

Watching the exhibitors clean up their displays at the end of the show, exhibit manager Fred J. Tabery remarked that the 1958 meeting had seen the biggest ISA show in history, bigger by 8,000 sq ft of display space. Most of those who attended were willing to agree that it also had been one of the most interesting from an engineering view.

CLIFTON PRECISION *can give you what you want*

in PRECISION COMPUTING RESOLVERS

Size 8
Wt.: 32 grams
Diam.: .750 in.

Size 11
Wt.: 90 grams
Diam.: 1.062 ins.

Size 15
Wt.: 160 grams
Diam.: 1.437 ins.

ACCURACY

Without any compensation or balancing, 60% of a recent production run of our precision computing resolvers showed functional errors of under .03%. Ninety-five percent of the units showed under .06% error.

Perpendicularity of axes is held to one minute of error in 90 degrees, or ±3′ on the full circle. Due to extreme symmetry of rotor and stator, nulls are excellent. Low phase shifts are an added feature.

VERSATILITY

Many types of Clifton Precision computing resolvers are offered including:

- *Sizes 8, 11 and 15*
- *Stainless steel housing and bearings (corrosion resistant) optional*
- *450°F High Temperature Units*
- *The following compensation available in any or all units:*
  - *Resistive*
  - *Feedback Winding*
  - *Thermistor*
- *Units suitable for use with transistors*
- *Pin or screw terminals or lead wires*
- *BuOrd type shafts available*
- *BuOrd MK 4 Mod 0 brush block configuration available*

PRICE AND DELIVERY

Rotary Components are our business. We have studied the efficient manufacture of synchros and resolvers for many years —with results that have enabled us to lower traditional prices substantially in the past. We ask you to review what you are paying for precision computing resolvers.

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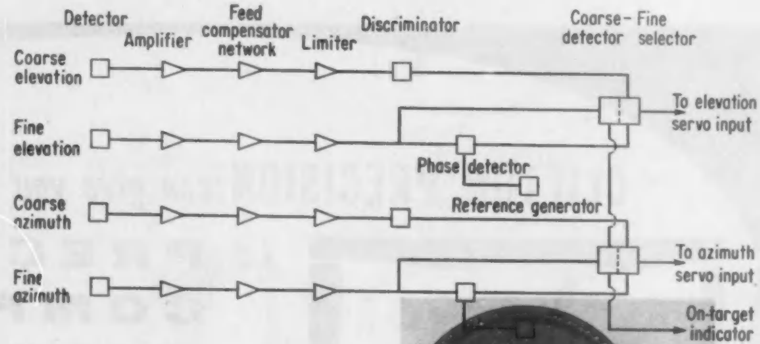
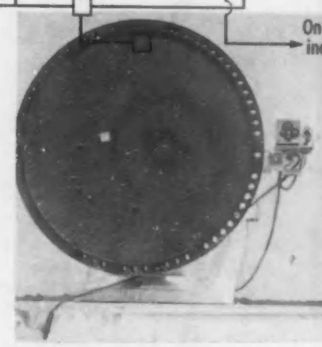




Infrared Eye

. . . improves accuracy of position data at missile launch, substitutes for photographic and radar tracking during crucial period.

CAPE CANAVERAL—New infrared tracking gear gives "second sight" to ground radar during the launching of missiles at the Air Force Missile Test Center. The new device, developed by RCA Service Co. engineers William Schupp and Charles Layne, improves the accuracy of launch position data, permits trackers to get an angular track not possible with other instrumentation. The new equipment was first used during the unsuccessful launch of the Army's Explorer V at the end of August; the IR tracking eye, built by Barnes Engineering Co., has been operational since.

Precise position data at time of launch has always been difficult to get. Dust and smoke swirling around the missile frequently hide it from photographic cameras. And ground scatter, reflections of the radar beam bounding off the ground instead of the missile, affect radar.

Main job of the new high resolution IR tracking system is to supply data during the period when radar information is degraded by ground clutter. Unencumbered by takeoff distractions, the IR tracking can handle the large amount of energy emitted in the near infrared spectrum by the exhaust flame. The tracker is zeroed in on the hottest point in the plume of the missile, then locks on and follows it. That means, for example, that the IR can be pinpointed on a spot, say 10 ft to the rear of a missile exhaust emitting a 40-ft flame.

This leads to another advantage of the IR gear: increased accuracy. The IR equipment is always zeroed in on the same point in the missile exhaust. Radar, on the other hand, continually jumps up and down the full length of the "bird", seriously depreciating the accuracy of launching data.

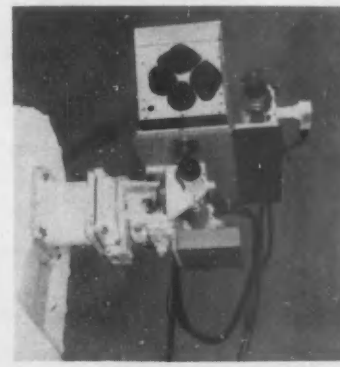
One limitation of the new gear is that it's blinded by cloud cover: clouds effectively shield out the infrared radiation. If this happens, the tracking system is switched back to radar tracking (ground clutter is rarely a problem by the time cloud cover is reached) by the IR equipment operator watching the launch on closed-circuit TV.

• **Design specifications** — The IR tracker consists of two major units; an optical receiver and an electronic unit. The optical receiver weighs 22 lb, is mounted on a camera bracket on radar antenna.

Initial specifications for the IR tracking gear were so severe they ruled out standard systems that had been previously developed for infrared viewing. Three critical requirements: 0.25 mil accuracy (later tightened to 0.01 mil); a wide total field of view 4 deg by 4 deg; and error signal time constant of 400 microsec.

It was the combination of these three that made conventional equipment unusable. Normally IR trackers

WHAT'S NEW



Four radiation collecting lenses are in optical receiver of IR tracker. TV camera for closed circuit viewing is mounted underneath.

obtain directional information from rotating reticules or mutation scans on a stationary reticule.

The RCA engineers, working with Barnes, developed a device consisting of multiple optical systems for coarse and fine tracking (see schematic). The coarse system sends maximum correction signals to the servos until the target gets into the fine system field; after that, proportional control is used

In the optical system, four identical radiation collecting lenses focus the same field of view on four different positions, spaced 90 deg apart around the edge of a 6-in. diameter rotating reticle. Each lens is associated with a separate function: 1) fine azimuth error sensing, 2) fine elevation error sensing, 3) coarse azimuth error sensing, and 4) coarse elevation error sensing.

The rotating reticle discriminates against large targets such as clouds and the horizon, and encodes incoming target energy so that position information is obtainable. To do this, the reticle rotates at 10 rps with three concentric bands of alternating opaque and clear bars chopping sensing fields. The two inner bands chop the coarse error sensing field; the outer band provides a reference-phasing signal and chops the fine error sensing field.

Germanium field lenses behind the reticle then focus an image of the objective lens onto the detector, rugged lead sulfide crystals capable of catching large amounts of energy and not requiring cooling. This distributes the radiation from a point target uniformly over the detector. It also eliminates the effect of variable sensitivity over the surface of the detector, reduces the size of crystal needed.

• **Optical separation**—Azimuth and elevation functions are separated op-

At panel in blockhouse, operator can watch flight on TV and control IR tracker.

tically—rather than electronically—by using phase or frequency discrimination. Although requiring four lead sulfide detectors and lenses instead of two, this arrangement simplifies the electronic design, improves equipment serviceability and reliability.

The readout of the preamps is an error voltage which is zero in the on-target position and increases linearly with off-axis displacement until the coarse field is reached; then the error voltage remains constant.

• **Downrange uses**—Possibly the next application of the infrared gear will be at downrange installations: to track nose cones on reentry. As the missile enters the atmosphere, it generates sufficient thermal energy to permit infrared tracking. Last spring, a number of infrared pictures were taken by the Army of a Jupiter reentry. The next step is to use the Schupp-Layne infrared device for automatic tracking. Such a system will need a two-channel radiometer, the IR tracker, a cine spectrograph, and photographic gear to serve as an optical evaluator at reentry point.

—Douglas Dederer
McGraw-Hill News

Autonetics Ties Computer to Machine Tool Control

Renewed determination to enter the industrial control field was shown by Autonetics Div. of North American Aviation at the Western Tool Show last month. Autonetics demonstrated how its transistorized digital computer RECOMP II could be used with a new three-axis version of its numerical control system NUMILL to cut the time span from design concept to tooling.

NUMILL uses tape directly from the digital computer. High precision optical feedback determines machine movement.

WHAT'S NEW

New High Temperature Measuring Techniques at NBS

New concepts, new techniques, and new instruments are coming from an accelerated program on high temperature studies.

In both the missile and the atomic industries, engineers are working with a new order of high temperatures—up to several million degrees in fusion studies. But the concept of temperature becomes vague at such unusual conditions; and measurement with conventional instruments is impossible. That's why the National Bureau of Standards has accelerated its high temperature research program to develop new methods of measurement and new techniques for standardizing measurements. This year the bureau will spend $1,200,000 on such work, a four-fold increase over last year.

Dr. Charles M. Herzfeld, chief of the Heat Div., where much of the high temperature measurement studies at NBS are carried out, has set three objectives for the speeded up program:

1) to make more precise measurements under ideal conditions and controls up to 2,800 deg C. Currently, optical pyrometers are used to make such measurements; usual accuracy is plus or minus 3 deg. NBS is shooting for a precision of plus or minus 1/10 degree.

2) Extend the range of high temperature measurements so that there is available a standard black body operating at 4- to 5,000 deg C. Now, the top temperature for a black body standard is the melting point of gold: 1,063 deg C.

3) To learn how to measure temperature under nonideal conditions, such as in the gases of a jet engine or rocket exhaust, and at extremely high temperatures.

• More accuracy—One of the first concrete results of the program is being tested now. It's a photoelectric pyrometer that will probably replace the presently used disappearing-filament optical pyrometer for measuring temperatures above 1,000 deg C. The basic optical system and disappearing filament principle are retained, but the brightness of the test body is compared photoelectrically rather than visually with that of the pyrometer lamp.

With this new device, NBS has obtained a precision of 0.1 deg C

. . . more important than measuring temperature is determining what happens to key variables...

when observing a black body at 1,100 deg C. Herzfeld hopes that it will be the standard photometer by next year. The machine, he says, is flexible enough to trade accuracy for speed if necessary. By that he means it can take 1 min, for example, to measure with a precision of 0.1 deg; or it can measure within 10 deg in a millisecond.

Herzfeld predicts that this photoelectric photometer eventually will replace the conventional pyrometer. As he puts it, "An optical pyrometer depends on the characteristics of the viewer's eye and how he feels; that's no way to make a measurement!"

• **New concepts**—Probably the most intriguing high temperature work under way at NBS is the effort in the areas over 10,000 deg and with nonideal conditions. Here the first problem is defining temperature. One common definition, based on the ideal gas law, says Herzfeld, falls apart at these extreme ranges because an ideal gas does not exist under such conditions.

More important than measuring temperature, NBS scientists feel, is measuring key variables and correlating their values to determine what is happening at these conditions. Herzfeld thinks that he will know all he has to know about any system if he can determine two things:

1) distribution of all particles of a system over their energy levels

2) rate of change of distribution

According to Herzfeld, the number of atoms in each quantum state is a more fundamental property than temperature. In principle this is always measurable. The next step is to make some kind of correlation between distribution of energy states and temperature.

Herzfeld says he'll be satisfied even if he cannot perform some kind of correlation as long as he can measure the distribution of energy states. Then he'll set up a new scale of what's happening in terms of what he measures.

Such information is not easy to use, Herzfeld cautions. It requires the techniques of statistical mechanics and the capability of high-speed computers. But it offers the first practical method for measuring what happens in nonideal, rapidly changing conditions.

To do this job in gases, NBS is

using spectrographic techniques. At present it's a three-step job: first measuring the shape of spectral lines; then calculating the number of electrons per cc of gas; finally, knowing the pressure of gas, ionization energy of gas, and density of electrons, calculating temperature.

Accuracy of such measurement today rarely gets as good as plus or minus 10 percent. That's because there are two "iffy" steps, says Herzfeld. Both are highly theoretical. First is the calculation of number of electrons; second is the calculation of temperature from electron densities. Herzfeld is aiming for improvements in both theory and experiment that will provide data with an accuracy of within 1 percent.

• **New instruments**—All this theory has a highly practical side, too, one that is likely to make a major change in the instrument business. The photoelectric photometer already seems sure to make a dent in the optical pyrometer business. Herzfeld envisions such applications as reading steel mill furnace temperatures in the laboratory office, with a permanent record supplied.

And he envisions a whole new crop of temperature instruments based on some kind of a miniaturized spectrometer. For one thing he is working on a spectrometer that is small enough to fit into the tail pipe of a jet airplane engine. Herzfeld sees it as a new way to measure engine efficiency. Some day, he says, there will be one on every jet engine; it will read into a dial that will tell a pilot how well his engines are working without bothering about temperatures.

Pipeline Control

. . . needs better interface detection equipment, AIEE meeting hears.

DALLAS—

The need for more development work before interface detection equipment—devices to report the change in products moving in a pipeline—becomes a reliable control system component was sharply emphasized by panel members discussing "Batch Interface Detectors" at the Electrical Conference of the Petroleum Industry, sponsored by the Petroleum Industry Committee of the AIEE, in September.

Panel members discussed a number of interface detection methods, in-

cluding the use of radioactive energy, the measurement of dielectric constant, the weighing of product specific gravity, and color methods.

C. W. Blackburn, technical consultant of the engineering development branch of Phillips Petroleum Co., set the theme of the session when he pointed out that reliability was the capability most lacking in the several types of interface detectors that had been used by Phillips.

Reliability of some systems, Blackburn said, is satisfactory, but the price seems excessive, considering the relatively simple job to be done.

Dr. H. R. Hancox, director of research of Great Lakes Pipeline Co., stated that fundamentally the dielectric method, or measurement of any physical property, suffers from three difficulties: (1) noise caused by passage or deposit of foreign materials in the line; (2) it is not possible to detect 100 percent of the interfaces because of the overlapping of values, and (3) it is necessary to interpret the sometimes complicated signal before deciding the point to make a cut.

• **The users' report**—One presentation that caused a lot of comment was that made by E. B. Turner, General Electric Co., reporting a survey of the use and planned use "of the tools of automation" in pipelines.

A questionnaire was submitted to each of 48 crude and products pipe line companes, covering 125,000 miles with 90 percent participation. It was made under the auspices of the transportation subcommittee of the AIEE Petroleum Industry Committee.

Turner said he was surprised by the amount of use and planned use of computers. Either present or future use for computers was expressed by 67 percent of the companies replying. The other 33 percent had no use for computers or were not willing to express an opinion. Three major areas of application covered by the survey: (1) dispatching aid; (2) operation aid; and (3) accounting and billing.

Participants in the survey said some of the equipment needs for unattended station operation are (1) a solid state analog to digital converter; (2) an inexpensive deviation detector; (3) an inexpensive rate of change detector.

The most common methods of safeguard were totalizing number of pulses, and redundancy or check-back.

Four other types listed were monitoring width of pulse, sequential frequencies, monitoring shape of pulse, and multiple frequencies.

—Kemp Anderson
McGraw-Hill News

WHAT'S NEW

Steel Industry Controls

. . . win new recognition for control engineers. Even production engineers seem satisfied with feedback systems.

The trend to wider use of sophisticated control systems in steel plants (first reported in CtE, May 1957, p. 22) is accelerating, according to views expressed by representatives of half a dozen of the nation's major steel producers, meeting at the Cleveland Convention of the Association of Iron & Steel Engineers. Apparently the industry is now ready to take the control engineer and his "radical ideas" seriously; even production-oriented mill engineers seem satisfied that adding feedback control systems of relatively flimsy appearance by steel's standards results in more savings than operational headaches.

Successes racked up by such systems, particularly in the control of strip thickness on cold mills, has mitigated the reluctance of mill engineers to listen to new ideas. And real increases in the production of on-spec strip by such mills has persuaded the steel companies to help control engineers get more knowledge of the nature and dynamics of steel-making and rolling processes. Republic Steel Corp., for example, is building a $6 million research center just south of Cleveland; U. S. Steel has broken ground at its Monroeville (Pa.) research center for a building to house its control research.

At the Iron & Steel Exposition, held in conjunction with the convention, the new trend was even more obvious. The traditional pushbuttons, motors and contractors and combustion controls were all on display. But so were the newest items of interest to sophisticated control engineers. Some of these products were shown for the first time only a week previously at the ISA show in Philadelphia.

Getting remarkable attention from the steel engineers was the Libratrol 500, GPE Controls' brand-new entry in the control computer market. GE's Computer Dept. also demonstrated its readiness to build control computers for the steel industry.

Another highlight at the show was a new static punched card reader displayed by GE. It uses photocells to avoid problems with dirty spring contacts (likely to be encountered by mechanical readers in steel mills).

—E. J. Kompass

AROUND THE BUSINESS LOOP

Control Companies Join Hands to . . .

GAIN VERSATILITY

Merger of Ling Electronics and The Calidyne Co. brings more impressive stature for both in the field of vibration equipment and testing.

According to a recent news release prepared for Ling Electronics, Inc., of Culver City, Calif., the merger of Ling with The Calidyne Co. of Winchester, Mass., has made the West Coast vibration controls maker the nation's largest producer of complete vibration systems. This can very well be the case; for Calidyne is an important manufacturer of electrodynamic shakers and control equipment for all ranges of vibration test programming, and even before the merger Ling was a leader in vibration amplifier systems.

The merger has another implication, too: it can mean that MB Electronics, said to be the biggest producer of vibration test equipment in the country, has been superseded in first position by the combination of the smaller Calidyne Co., and an important manufacturer of high-power, electronically driven vibration amplifiers and vibration control systems.

• **New testing system**—Under an integration program now being carried out by Ling and Calidyne, all vibration systems and components will be sold and serviced in the East by Calidyne and in the West by Ling. One of the first products bearing the stamp of both companies is a giant vibration testing system said to be almost twice as powerful as any now in operation. It has a large power amplifier rated at 240,000 watts output and an electrodynamic shaker capable of delivering 25,000 pounds-force. It will be used by a major prime contractor in developing an advanced type of missile.

Ling is responsible for the first random-wave testing equipment and for perfection of shaker protective devices that allow uninhibited random or sine wave testing. Under Calidyne's belt are a 24-channel multiple shaker system for aircraft ground vibration studies, the first 2,500-pound-force shaker system, and the first 25,000 pound-force shaker with automatic control.

STUDY A PROBLEM

Out of a T-R-W Products-SOhio agreement may come a new definition of the role of the digital computer in automatic process control.

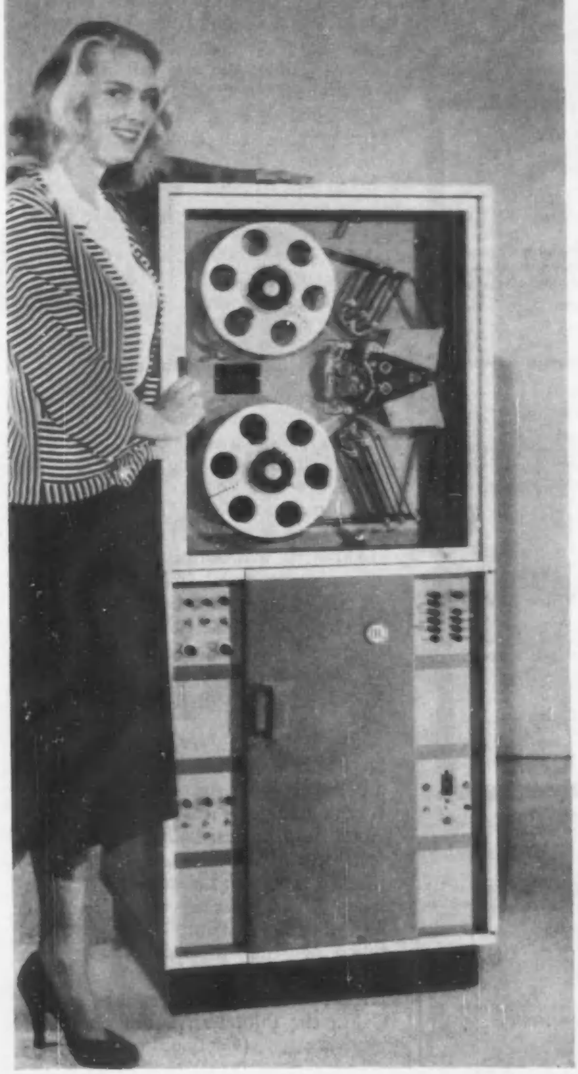
At the annual Instrument-Automation Conference at the ISA meeting in Philadelphia in September, it was announced that The Thompson-Ramo-Wooldridge Products Co. had entered into an agreement with Standard Oil of Ohio to study the application of digital computers to automatic process control. Initial beneficiaries of the study will be the oil company's refinery units. Out of the study are expected to come new control techniques and equipment.

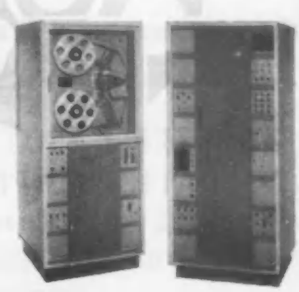
Significantly, the Los Angeles products company, jointly owned by Thompson Products and Ramo-Wooldridge, has just organized a new Engineering Div., whose inclination seems to be toward processes. The four departments making up the new division deal with process applications, data processing and controls, project engineering, and programming. Three of the departments already have permanent managers and one has an acting manager.

• **Two CtE authors**—Thomas M. Stout, a CtE author (February '56, page 57, and April '56, page 77), is in charge of the Process Application Dept. His associate is Charles G. Laspe. This department is responsible for joint applications studies with companies in the petroleum refining, chemical, and other process industries that are planning to install computer control systems.

The Data Processing & Controls Dept. is under the wing of James A. Trapp, currently on assignment to the Process Applications Dept. He will take on his new duties shortly. His associate manager is Harold A. Keit. Trapp's department will study new applications for computing control systems.

William S. Aiken, another CtE author (October, page 76), has been named manager of the Project Engineering Dept., which will handle the installation and check-out of computer





The basic MicroSADIC consists of a commutator, digitizer, system programmer, time programmer, and digital tape unit. All-transistor circuitry on printed boards results in low power consumption and trouble-free operation.

control and data logging systems. In addition, Aiken will serve as acting manager of the Programming Dept.

Henry L. Bechard, formerly with Daystrom Systems, has been named customer relations manager of special control and data reduction systems by the Thompson-Ramo-Wooldridge firm. At Daystrom, Bechard was responsible for administration and coordination of the Engineering Dept. He is also familiar with electro-optical tracking systems and telemetry.

Space Administration Takes Over NACA

The new Space Act stipulates that all that has been the National Advisory Committee for Aeronautics must be transferred into a new body to be known as the National Aeronautics & Space Administration within 90 days after the act is signed. Since President Eisenhower signed the act on July 29, things have moved rapidly, and it is now disclosed that that transfer has taken place with a month to spare.

"One way of saying what will happen," explained NASA Administrator T. Keith Glennan, now on leave as president of Case Institute, "would be to quote from the legalistic language of the Space Act: 'The NACA shall cease to exist . . . (and) all functions, powers, duties, and obligations and all real and personal property, personnel (other than members of the committee), funds, and records of that organization' shall be transferred to NASA.

• **A metamorphosis**—"My preference is to state it in quite a different way. That what will happen . . . is a sign of metamorphosis. It is an indication of the changes that will occur as we develop our capacity to handle the bigger job that is ahead. We have one of the most challenging assignments that has ever been given to modern man."

Three main NACA laboratories were renamed in the changeover. They are the Langley Aeronautical Laboratory at Langley Field in Virginia, the Ames Aeronautical Laboratory at Moffett Field in California, and the Lewis Flight Propulsion Laboratory in Cleveland, Ohio. In each case, "research center" was substituted for the words following the proper names. No change of name is pending for the High Speed Flight Station, Edwards, Calif.; the Pilotless Aircraft Research

(Continued on page 168)

New amplifier battles "noise"

Four-stage junction diode amplifier was developed at Bell Telephone Laboratories by Rudolf Engelbrecht for military applications. Operates on the "varactor" principle, utilizing the variable capacitance of diodes. With 400-mc. signal, the gain is 10 db. over the 100-mc. band.

The tremendous possibilities of semiconductor science are again illustrated by a recent development from Bell Telephone Laboratories. The development began with research which Bell Laboratories scientists were conducting for the U. S. Army Signal Corps. The objective was to reduce the "noise" in UHF and microwave receivers and thus increase their ability to pick up weak signals.

The scientists attacked the problem by conducting a thorough study of the capabilities of semiconductor junction diodes. These studies led to the conclusion that junction diodes could be made to amplify efficiently at UHF and microwave frequencies. This was something that had never been done before. The theory indicated that such an amplifier would be exceptionally free of noise.

At Bell Laboratories, development engineers proved the point by developing a new kind of amplifier in which the active elements are junction diodes. As predicted, it is extremely low in noise and efficiently amplifies over a wide band of frequencies.

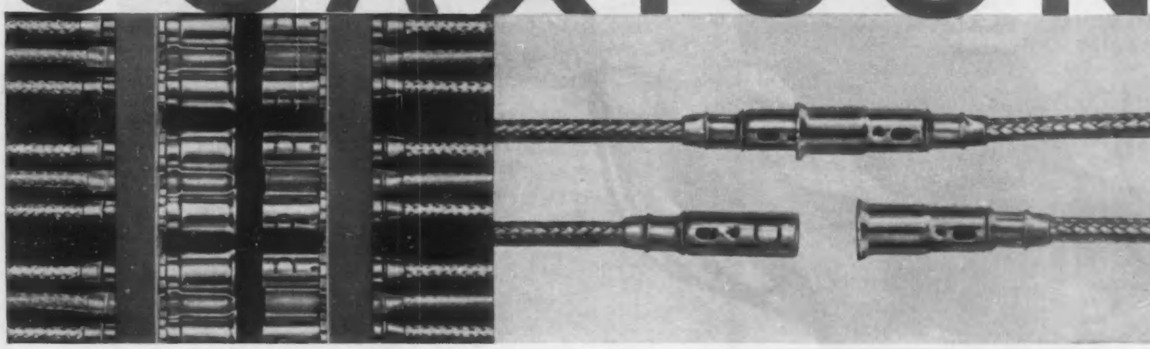
The new amplifier is now being developed for U. S. Army Ordnance radar equipment. But it has numerous other possibilities. In radio astronomy, for example, it could be used to detect weaker signals from outer space. In telephony, it offers a way to increase the distance between relay stations in line-of-sight or over-the-horizon communications.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

THE NEW CONCEPT IN COAXIAL DISCONNECT SPLICING...

COAXICON



Here is a totally new method for attaching disconnect splices to coaxial cables that will create new standards of performance . . . on chassis connections, computers, test equipment—in fact, anywhere that two coaxial cables need fast and reliable disconnect splicing.

Easily attached to coaxial cables by AMP's modern compression method, the all new A-MP COAXICON assures you of uniformity, absolute reliability and new low cost—in either free-hanging or through-panel units. In addition, the COAXICON supports cable shielding against vibration while offering fully insulated positive electrical performance.

Production rates easily exceed any method you're now using. With a simplified wire stripping method, it takes just one stroke of the matching A-MP tool to permanently crimp COAXICON to your coaxial cable.

Think of it—no more burned or melted insulation, no doubtful, sloppy connections, no time consuming, high-cost assembly methods. Once you've seen the all new COAXICON, you won't settle for less.

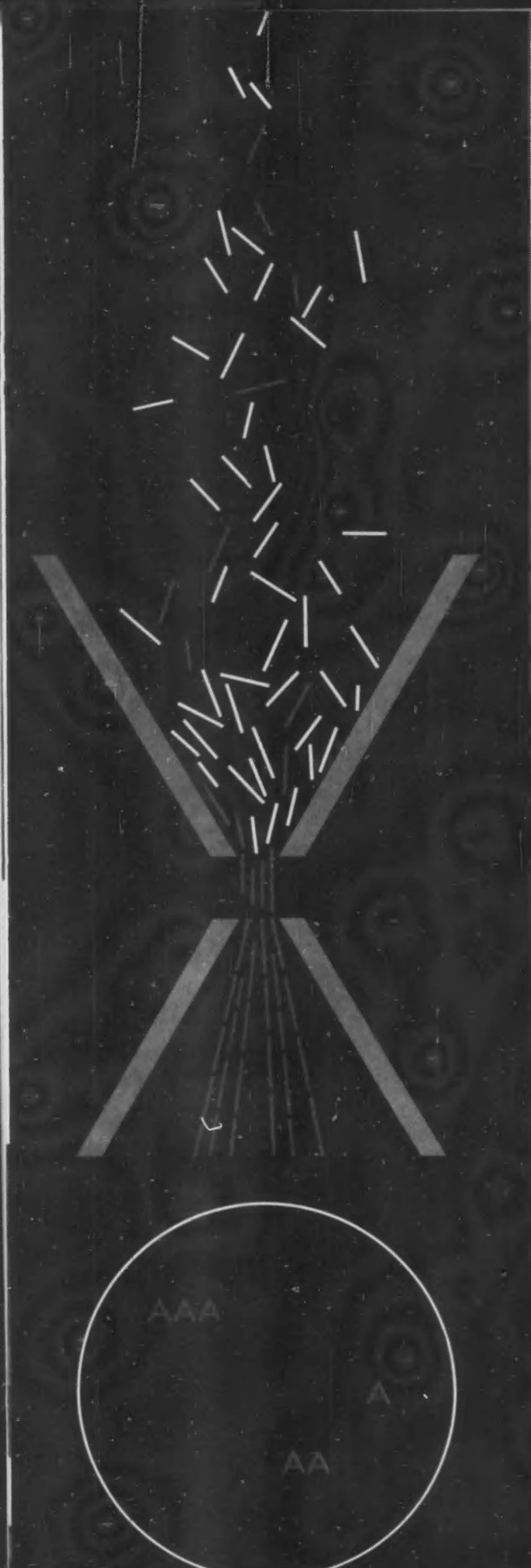
Send for a sample and complete product information today.

AMP INCORPORATED

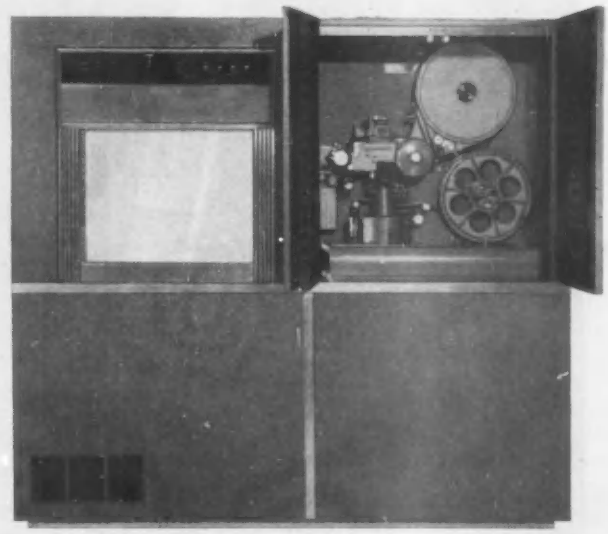
GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through subsidiary companies in: Canada • England • France • Holland • Japan

 CIRCLE 39 ON READER-SERVICE CARD CIRCLE 40 ON READER-SERVICE CARD →



Leaders in Readout and Display . . .



S-C 4000

Series of High-Speed Microfilm Printers

Pictured above is the S-C 4010, one of several High-Speed Microfilm Printers that comprise the S-C 4000 Series. This unit, custom-developed for use with the Naval Ordnance Research Calculator, serves a three-fold purpose: recording data on microfilm at speeds up to 15,000 characters per second, plotting data on microfilm at speeds up to 10,000 points per second, and projecting selected data on a direct-viewing screen less than eight seconds after film exposure.

Two other models in the series are the S-C 4000 — developed for use with the Livermore Automatic Research Computer — and the versatile S-C 4020 — capable of both *on-line* and *off-line* operation and equally adaptable to either business or scientific applications.

Write today for further information concerning the S-C 4000 Series of High-Speed Microfilm Printers . . . outstanding examples of Stromberg-Carlson leadership in the field of readout and display.

STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS CORPORATION
1895 Hancock Street, P.O. Box 2449, San Diego 12, California

Developers and Manufacturers of S-C 1000 Direct Viewing Displays • S-C 2000 Bright Displays • S-C 3000 High-Speed Communications Printers • S-C 4000 High-Speed Microfilm Printers • S-C 5000 High-Speed Electronic Printers

"There is nothing finer than a Stromberg-Carlson"

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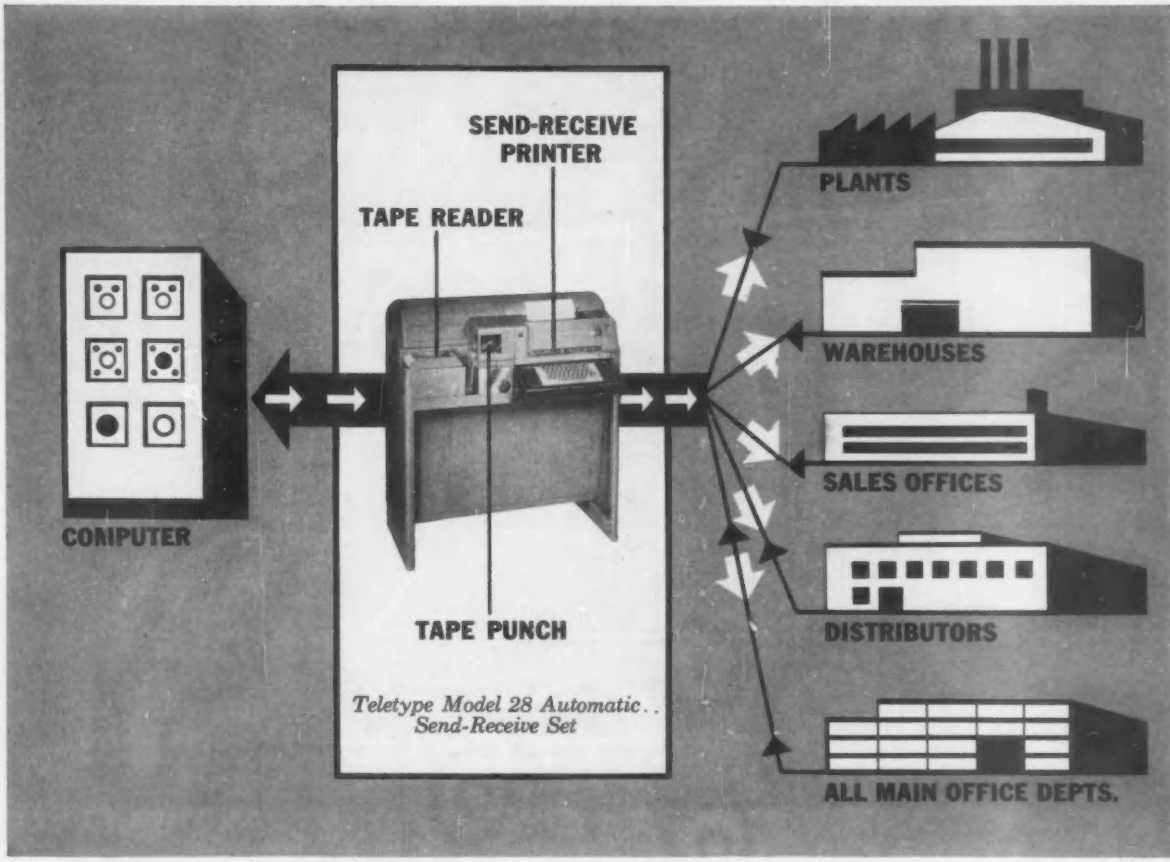

New Teletype unit provides a two-way link for office-to-computer operations

The Teletype Model 28 ASR serves a dual purpose in the *office-to-computer-to-office* data processing chain. This versatile unit functions as:

1. IDP equipment for local operations in offices and computer center . . . *and*

2. Communications equipment between offices and computer center.

Data is programmed, edited and stored utilizing the tape punch. This single, initial operation is the only "keyboarding" required. Data from tape is automatically transmitted by tape reader to the computer center where it is received in tape form.

After computation—the resultant data is transmitted back through the ASR to any or all office locations.

A New Application—The Teletype Model 28 ASR gives you an accurate method of testing and checking data processed through a computer installation.

METHOD: Test data on tape is fed into a computer through the Model 28 ASR tape reader. The resultant computer output is recorded on the page printer of the Model 28 ASR for comparison with a known answer.

For more information on the New "100 Word Per Minute" Teletype Model 28 ASR and what it can do . . . use coupon below.

TELETYPE® CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

TELETYPE CORPORATION
Dept. 20-L, 4100 Fullerton Avenue, Chicago 39, Illinois
I'd like a copy of the free booklet describing the NEW Model 28 ASR.
NAME _____
COMPANY _____
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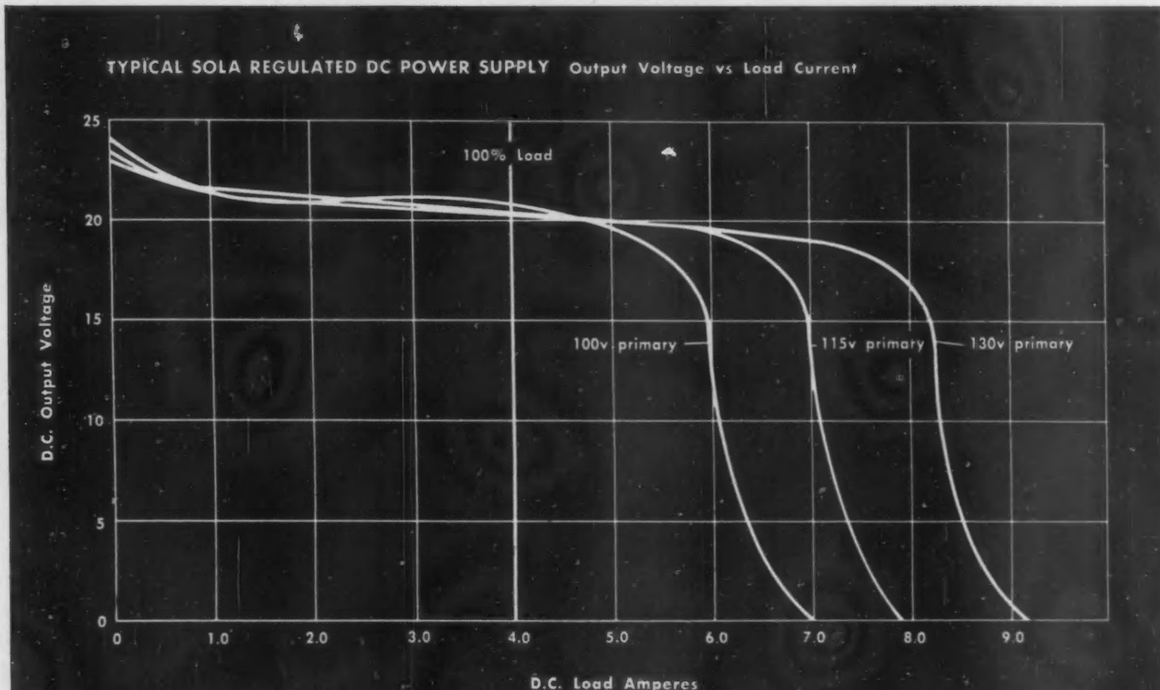
CIRCLE 43 ON READER-SERVICE CARD



Curves covering output voltage of a Sola Constant Voltage DC Power Supply show flat regulation between 25% and 100% of rated load, and rapid drop to zero beyond — illustrating its current-limiting characteristic.

RELIABLE, regulated DC power supply

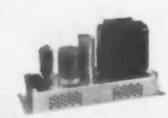
Here's a regulated dc power supply that will protect its load and itself from a fault or short beyond the primary of its power transformer. If you're interested in a simple, reliable source of regulated dc power, you'll like the Sola Constant Voltage DC Power Supply.

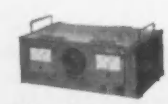
This very desirable load protection characteristic results from the current-limiting action of the Sola Constant Voltage Transformer. It is combined with a semiconductor rectifier, and a high-capacitance filter. The current-limiting action protects both the rectifier and capacitors from damage by preventing excessive charging current.

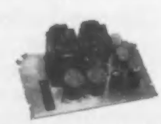
This unique combination of components results in a power supply that is unusual in other ways as well. Regulation is within ±1% with up to 10% line voltage variation . . . ripple within 1% rms . . . efficiency is high. It's also well-suited for intermittent, variable, and pulse loads.

The Sola dc supply is reliable, simple, compact, and moderately-priced.

Write for Bulletin 26K-DC-235


Fixed output — six ratings available from stock


Adjustable output — six ratings from stock


Custom-designed units produced to your specs

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 18, Ont.

SOLA


CONSTANT VOLTAGE TRANSFORMERS


REGULATED DC POWER SUPPLIES


MERCURY LAMP TRANSFORMERS


FLUORESCENT LAMP BALLASTS

A DIVISION OF BASIC PRODUCTS CORPORATION

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AIRPAX CHOPPERS

Characteristics for every application

Airpax makes all types of choppers

Most types are available in variations of mounting styles, terminal headers and temperature ranges.

Airpax types 175, for 60 CPS and 300, for 400 CPS, are considered "standard types" because of their universal applications. Large quantities are produced and sold yearly. They perform faithfully in critical circuits year after year without attention.

The center pivot used in type 371 braces the vibrating armature against extremes of shock and vibration. Type 199 is suitable for VHF direction finding equipment while type 600 has a DPDT contact arrangement for multiple signal mixing.

Type 2300 is a new low noise chopper in which special constructional features reduce chopper contact noise to one microvolt or less.

All Airpax choppers are accorded the same care and attention in manufacture and test whether production is large and continuous or limited.

THE CONTACT MODULATOR

Several parts of the new Chopper Series are now available. Write for free copies.

AIRPAX

AIRPAX PRODUCTS COMPANY
CAMBRIDGE DIVISION
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OPERATION up turn — Buy now for extra values — GENERAL ELECTRIC

COMPUTER PROGRESS

Digital and Analog Computers at Work

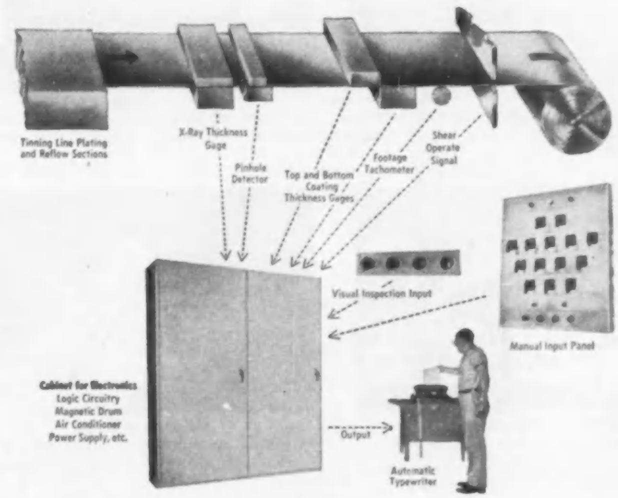
ARTICLE 3 VOLUME 1

SOLVING A TINPLATE INSPECTION AND BILLING PROBLEM WITH MODULAR COMPONENTS

The trend towards purchasing tinplate direct in large coils rather than in sheets brings about a change in inspection techniques. No longer is it possible to separately inspect each sheet; instead, inspection must now be done at line speed on the delivery end of the tinning line. As complete coils of tinplate will now be shipped to the customer, steel companies will need permanent, accurate defect records.

General Electric is now solving this problem for several tinplate producers by *automating* their data logging with the new Model 302 Automatic Inspection Data Accumulator for Tinplate. This system provides a complete, typewritten record for quality control and billing purposes immediately upon completion of each coil.

Unlike many computers installed in factories, the G-E Data Accumulator is designed specifically for an industrial environment, not for office use. Modular electronic units are mounted on strong, 3/16 inch metal frames in completely enclosed cabinets. The all-transistorized plastic coated printed circuit plug-in cards are easy to repair; maintenance costs are reduced since cards may be reused, and spare parts stock is kept small.



In addition, an exclusive new magnetic drum application cuts out approximately 60% of previously required electronic gear. Not only does the reduction in complexity increase reliability, but the space and dollar saving also allows sufficient duplication of circuitry for constant cross-comparison of data. Preventive maintenance can be performed on one section while the other continues to log data. Magnetic storage also eliminates the danger of losing stored data if power fails.

COMPUTING SERVICES GROUP HANDLES COMPLEX ORIGIN-DESTINATION STUDY FOR WESTERN CITY

The Computing Services Center of the G-E Computer Department recently completed an origin-destination tabulation for the Phoenix-Maricopa County Traffic Study Group in Phoenix, Arizona. The results of this tabulation, when analyzed, will enable the group to plan the street and highway development program of this desert metropolis for years to come.

Using manual, or simple computing methods, such tabulations often take many months—sometimes years—to complete. However, using the Computing Services Center Computer on a rental basis, the job was completed in just a few weeks. The Computer Department also performed the difficult programming job.

The Computing Services Center of G-E's Computer Department is staffed with 125 analysts, programmers, coders—all leaders in the computer field. Their services are available, along with time on the large and versatile type 704 computer, to handle the problems of industry, business, government and education.

ONLY 8 HOURS INSTRUCTION REQUIRED TO OPERATE PRODUCTION SCHEDULING COMPUTER

The new G-E 306 desk-size analog computer, designed to solve office and factory production and business problems, can be operated by the average clerical worker after only 8 hours instruction.

The computer is used wherever multiplication of a number by each of fifty coefficients and the summing of the results is required. Up to twenty-four such numbers may be multiplied with one setting of dials. Manufacturing problems such as production scheduling, materials explosion and work station load impact studies, as well as business problems like budget syntheses and operating reports (or any other first order linear equation problem) may be solved.

A typical solution takes only 2 minutes. The unit operates on 115 volts.

For more information, contact your nearest General Electric Apparatus Sales Office, or Computer Department—Room 102, General Electric Company, 1103 No. Central Avenue, Phoenix, Ariz.

CPA—9

Progress Is Our Most Important Product

GENERAL ELECTRIC

TELETAX* TELEMETERING

by Foxboro...

engineered for the most advanced transmission techniques

Telemetering matched in performance with famous Foxboro instruments — that's the Foxboro Teletax Telemetering System.

Through use of impulse-duration signals, Teletax electrically transmits measurements of a remotely-located variable to the central control station. Here, the Teletax receiver records the duration of impulse, which is directly proportional to the measured variable.

The Foxboro Teletax System is noted for its simplicity, its versatility, and its high sustained accuracy. For a transmission medium, it can use either AC or DC, an audio frequency carried on a transmission line, or radio or microwave impulses. Sustained accuracy is 0.5% of full scale.

TELETAX RECEIVERS

Teletax receivers include: Single or Dual Receivers; Multi-Record Receivers for recording up to 6 separate measurements on one chart; and Teletax Receiver-Controllers for automatic operation. And the Teletax signal can be simply converted to digital information.

TRANSMISSION LINK

With Foxboro's Teletax Telemetering System, you can use the most advanced transmitting techniques: two wire lines, power lines, radio or microwave. As many as 25 different signals can be handled in each direction, simultaneously.

TELETAX TRANSMITTER

The Teletax Transmitter houses either one or two standard Foxboro measuring elements — plus the Teletax transmitting mechanism. It will transmit to a control center hundreds of miles away just as easily as to one nearby. It also indicates or records locally if desired.

The Teletax Transmitter needs *no* periodic maintenance whatever, while the receiver requires only occasional oiling. And the receiver has a minimum of mechanical components to wear — no clutch to slip or jam.

Foxboro Teletax Systems are now in wide use on natural gas systems, water works, oil fields, power plants, steel mills, etc. Write for Bulletin 17-11C — it gives all the details. The Foxboro Company, 3611 Norfolk Street, Foxboro, Mass.

*Reg. U. S. Pat. Off.

FOXBORO

REG. U.S. PAT. OFF.

TELETAX TELEMETERING

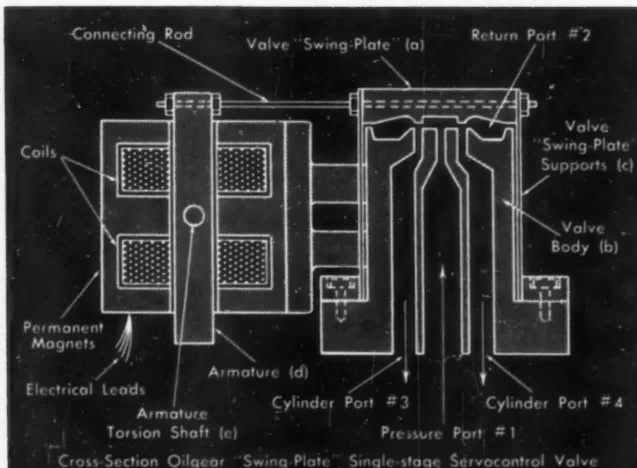
CIRCLE 49 ON READER-SERVICE CARD

...Fluid Power **news**

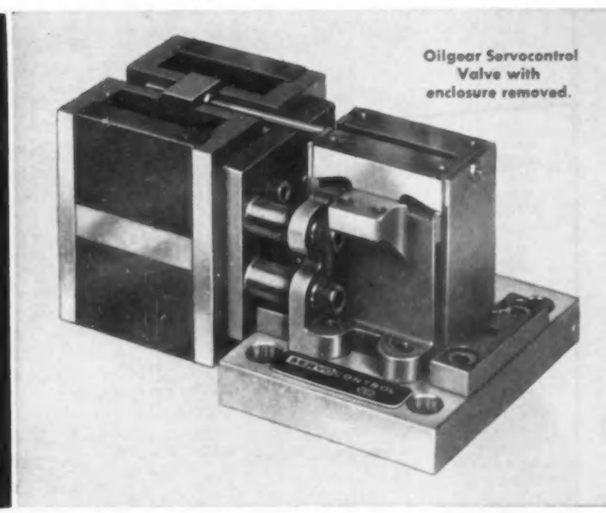
NEW INDUSTRIAL SERVO-CONTROL VALVES

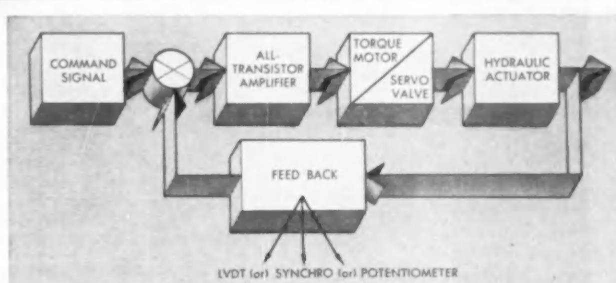
New Oilgear Electrohydraulic Servocontrol Valves

SERVO VALVE DESIGN OBJECTIVES: 1: Greater control accuracy and resolution for rotation and straight-line drives. 2. For industrial applications, must be capable of controlling wide pressure and volume range with single-stage, fast response to a low input signal. 3. Eliminate conventional valve frictional problems between spools and cylinders. 4. Eliminate two-stage linkage and stability problems. 5. Eliminate first-stage pilot systems — supply pressure, centering devices, filters, and orifices required for pilot systems. 6. Provide a flow rate substantially linear to valve displacement, with stability in null position. 7. Eliminate or substantially reduce valve "dead-band," sticking, jamming, scoring. 8. Be "fail-safe." 9. Operate safely in hazardous locations.



Cross-Section Oilgear "Swing-Plate" Single-stage Servocontrol Valve
*Patent Pending


Oilgear Servocontrol Valve with enclosure removed.



SOLUTION: **1.** A new concept of three and four-way single-stage electrohydraulic servo valve construction . . . only two moving parts in Oilgear's new "Swing-Plate" design. **2.** No metal-to-metal contact between "Swing-Plate" (a) and valve body (b) . . . frictionless for high sensitivity, fast response to minute signals — virtually eliminates sticking, scoring, jamming. **3.** Clearances and port seal sizes can be varied to suit application and fluid handled. **4.** Sharp, long rectangular chambers and lands linearize valve characteristics — flow rate essentially a linear function of valve displacement . . . supply high fluid power gain with minute "Swing-Plate" movement. **5.** Hardened stainless steel construction assures reliable operation well in excess of a hundred million cycles, even with non-lubricating fluids. **6.** No pilot system pressure, centering devices, orifices, or internal filters required. **7.** Spring-steel supports (c) respond instantly to low torque motor forces. **8.** As torque motor armature (d) pivots on torsion shaft (e), valve automatically centers in event of power failure for "fail-safe" operation. **9.** For operation above 500 psi, a compensating cap equalizes hydraulic forces to maintain selected clearances. **10.** No special modification required for use in hazardous locations. **11.** Valves — open or enclosed — can be gasket-mounted. Pipe tap subplates are available.

PERFORMANCE DATA: Flow Rate — 4 gpm at 250 psi; 8 gpm at 1000 psi pressure drop across valve. Supply Pressures — to 3000 psi. Torque Motor; Mid Position Force — 11 lb min.; 5 watts max. power demand; Stroke — ± 0.015 inches; Hysteresis — less than 3%; Differential Current — 150 ma; Resistance per Coil — 80 ohms. Other coil current and resistance values available. Net Weight — 4¼ lb. Width: 4¾"; Height: 2¾"; Depth: 3".

Oilgear can supply all components for Fluid Power Servocontrol systems . . . all-transistor amplifiers, manual controls, preset controls, two-stage servo valves, variable displacement pumps, variable speed drives, motors and cylinders.

New Oilgear Servocontrol components applied to controls on Oilgear pumps and transmissions provide greater system accuracy and resolution. Functions easily attained with new Oilgear Servocontrol open and closed-loop systems are: 1. Precision, high-response speed control from zero to maximum rpm in either direction through remote control stations or switches. 2. Positive, high response, follow-up position control through remote command units. 3. Output motions or speeds with closed-loop systems will remain near constant with accuracies from 0.1% to 1.5%, and with resolution down to 0.05%.

For further information on these new valves and systems, call your Oilgear Application-Engineer. Or write, stating your specific requirements, directly to . . .

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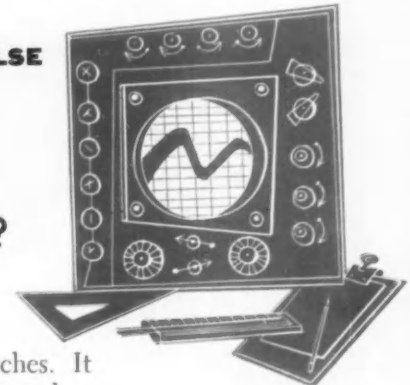


Soviet Control Makers:

can they capture the international market?

A youthful Soviet control industry is busting its breeches. It is virile and somewhat erratic, but it is concentrating on producing bread-and-butter control items. U.S.S.R. collected statistics show that production of control products in the Soviet Union has tripled in four and a third years, while that of the U. S. has tripled in 10 years. The Russians also claim that prices of these products decrease 3 percent per year. In contrast, U. S. prices have increased about 7 percent per year.

Soviet brandmarks

Such favorable trends are why the Soviets feel they can capture a big share of the international control market. If the U.S.S.R. can sell a trade agreement to the United States, American manufacturers will start meeting, in increasing numbers, the Soviet brandmarks seen on the next page. These identification marks will be affixed to mass-produced system components such as transducers, recorders, relays, controllers, drives, and valve actuators—and to some of the more prosaic systems, too.

V-brand

According to Soviet plans, each brandmark will be identified with a rather narrow product line, rather than a broad line that would cover most of a customer's applications. For example, V (for "Vibrator" plant in Leningrad) will appear on low-cost dc and ac meters and an eight-channel oscillograph. Production of this plant, and the goal for 1960, compared to a base of 1950 = 100:

TYPES OF INSTRUMENTS	1950	1952	1954	1956	1960 (est.)
Oscillographs	100	115	151	217	494
Switchboard electrical measuring instruments	100	169	193	315	469
Precision electrical measuring instruments	100	155	249	297	978

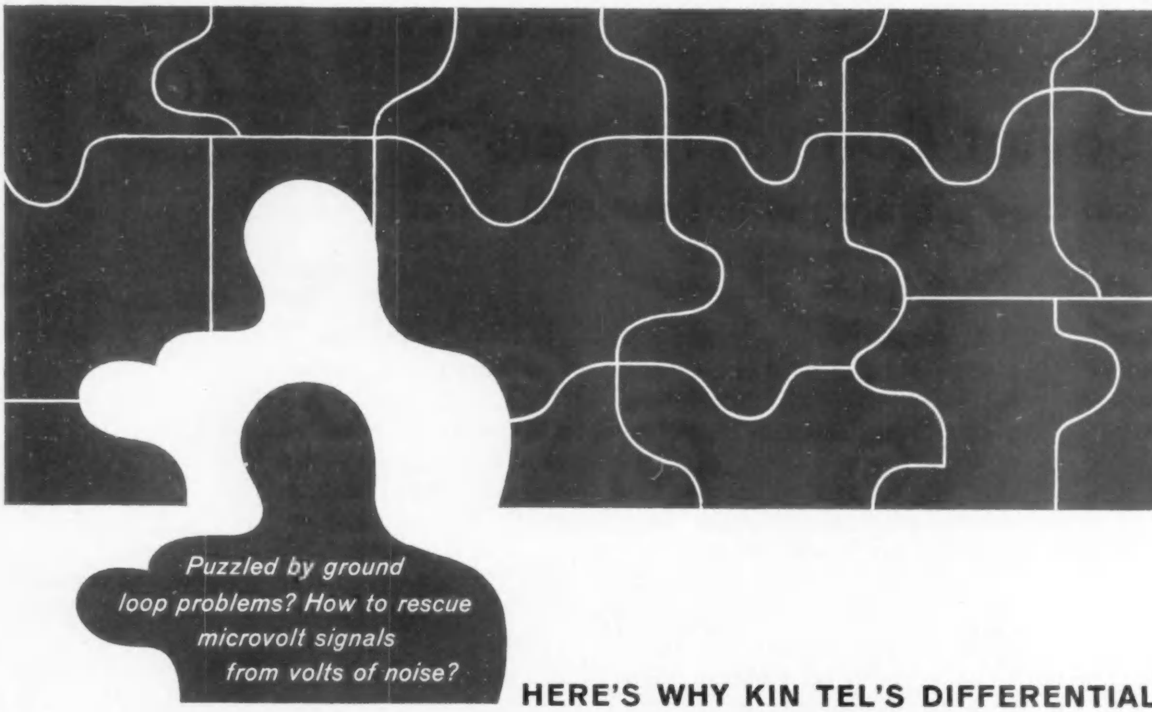
Annual production at this plant in 1957 was reputed to be 300,000 instruments, valued at 120 million rubles (roughly $15 to $20 million, depending on how you figure the exchange rate); employment reached 3,000 people. "Vibrator" has an absolute Soviet monopoly on the eight-channel oscillograph; it produces 300 of them per month, sells them at 5,000 rubles each.

Part of "Vibrator's" output is already finding its way into international trade channels. Its products now go to 30 countries, among them Czechoslovakia, Argentina, India, and China.

M3M mark

M3M, the brandmark of the Moscow "Manometr" plant, will appear on self-balancing recorder-indicators (present production: 2,500 per month on an assembly-line basis), mechanical pressure gages and manometer indicators (500 types and ranges; total present production, 40,000 per month), and differential pressure transmitters (current production: 800 per month).

Price of "Manometr's" circular chart, single pen, electronic recorder has dropped from 3,300 rubles in 1949 to 2,360 rubles



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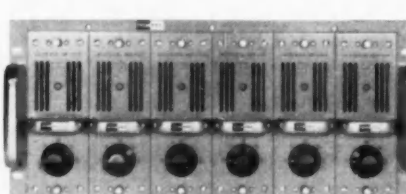
160 db DC, 120 db 60 cycle common mode rejection with balanced or unbalanced input ■ Input completely isolated from output ■ Input and output differential and floating ■ 5 microvolt stability for thousands of hours ■ .05% linearity, 0.1% gain stability ■ Gain of 10 to 1000 in five steps ■ >5 megohms input, <2 ohms output impedance ■ 120 cycle bandwidth ■ Integral power supply

These are just a few of the many outstanding features of the Model 114A differential DC amplifier . . . features that make this amplifier *really work* in instrumentation systems . . . features that will help solve *your* instrumentation problems today.

Ideal for thermocouple amplification, the 114A eliminates ground loop problems; allows the use of a common transducer power supply; permits longer cable runs; drives grounded, ungrounded or balanced loads, and can be used inverting or non-inverting.

For additional information and technical literature on this exceptional instrument, write or call KIN TEL – the world's largest manufacturer of precision, chopper-stabilized DC instruments.



KIN TEL 114A differential DC amplifiers . . . convenient, interchangeable plug-in mounting in either 6-amplifier 19" rack mount modules or single-amplifier cabinets.

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 CIRCLE 52 ON READER-SERVICE CARD

today. Manometr's miniature strip-chart electronic recorder, however, is still not in full-scale production. Currently selling for 4,500 rubles, it will have its price cut 40 percent when assembly-line production starts, making it more nearly competitive price-wise.

Don't sell short

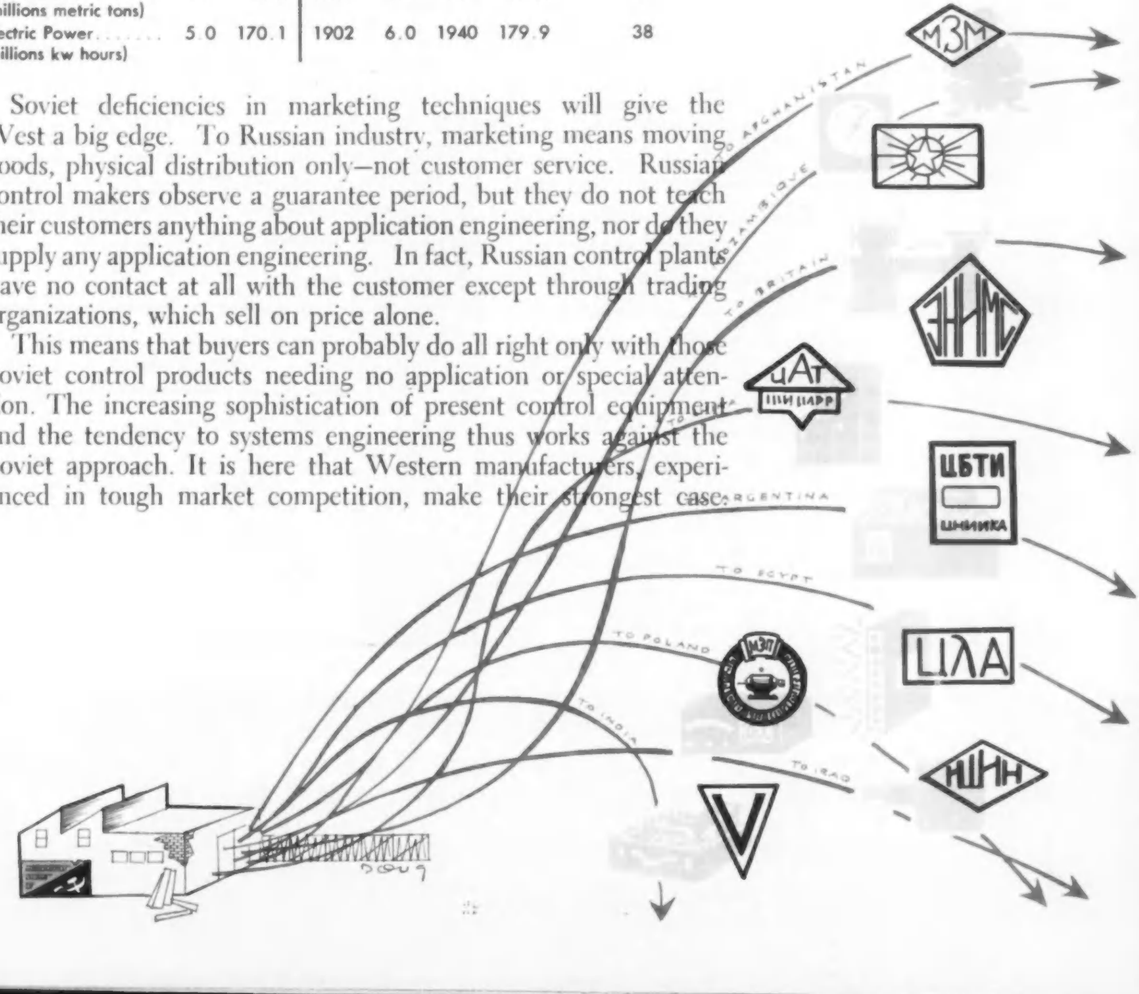
All this appears to signal the doom of U. S. dominance in international control markets. But sounding a death knell is quite premature. It is easy to be awed by the rate of growth in Soviet output when you don't examine totals closely and forget that the U. S. has two edges the Soviets may never overhaul: 1) quality of control products measured in better designs and greater reliability; and 2) vastly superior customer service.

Last year, the Legislative Reference Service of the Library of Congress studied several key Soviet production figures for 1928 (when Soviet industrialization began in earnest) and 1955. The study showed that Soviet gains were, on the average, matched by advances scored by the U. S. in far earlier periods. These figures, undeniably impressive, testify to the youth of Soviet industry, not its innate superiority over U. S. Typical statistics:

Item	SOVIET PRODUCTION 1928	SOVIET PRODUCTION 1955	U. S. PRODUCTION Date	U. S. PRODUCTION Amount	U. S. PRODUCTION Date	U. S. PRODUCTION Amount	No. of years for U. S. to reach 1955 Soviet output
Tractors (thousands)	1.3	163.4	1909	2.0	1919	164.6	10
Trucks (thousands)	0.7	329.0	1904	0.7	1920	321.8	16
Crude Petroleum (millions metric tons)	11.6	70.8	1902	12.0	1922	75.2	20
Steel (millions metric tons)	4.3	45.3	1890	4.3	1917	45.8	27
Electric Power (billions kw hours)	5.0	170.1	1902	6.0	1940	179.9	38

Soviet deficiencies in marketing techniques will give the West a big edge. To Russian industry, marketing means moving goods, physical distribution only—not customer service. Russian control makers observe a guarantee period, but they do not teach their customers anything about application engineering, nor do they supply any application engineering. In fact, Russian control plants have no contact at all with the customer except through trading organizations, which sell on price alone.

This means that buyers can probably do all right only with those Soviet control products needing no application or special attention. The increasing sophistication of present control equipment and the tendency to systems engineering thus works against the Soviet approach. It is here that Western manufacturers, experienced in tough market competition, make their strongest case.



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2N386—60v. germanium power transistor for servo amplifiers, high power-high voltage audio circuits, servo amplifier output stages, dc.-to-dc. converters and high power relay drivers.

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2N496—very low saturation resistance, high switching speed PNP Silicon surface alloy transistor for high temperature counters and logic elements.

2N501—high gain, super high frequency germanium micro alloy switching transistor for use in extra high frequency counters, logic circuits and wide-band video amplifiers.

2N502—very high frequency small signal amplifier micro alloy transistor for general purpose amplification at frequencies up to 400 m.c.

2N535—micro-miniature high gain, general purpose audio frequency germanium PNP junction transistor for use in metering decoders, signal amplifiers and telemetering applications where outstanding reliability is required in minimum space.

2N598—medium frequency, medium power, high current PNP alloy junction transistor for counters and logic circuits.

2N600—studded version of 2N598 for applications requiring higher power dissipation.

2N670—very high peak current, high voltage, low frequency PNP germanium alloy junction transistor in JETEC-type package. The 2N670 is specifically engineered for pulse modulators and pulse line drivers.

2N671—specially studded version of 2N670 for applications where high average dissipation is encountered.

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CIRCLE 53 ON READER-SERVICE CARD

Control
ENGINEERING
NOVEMBER 1958

If You Reported On Control Inside Russia . . .

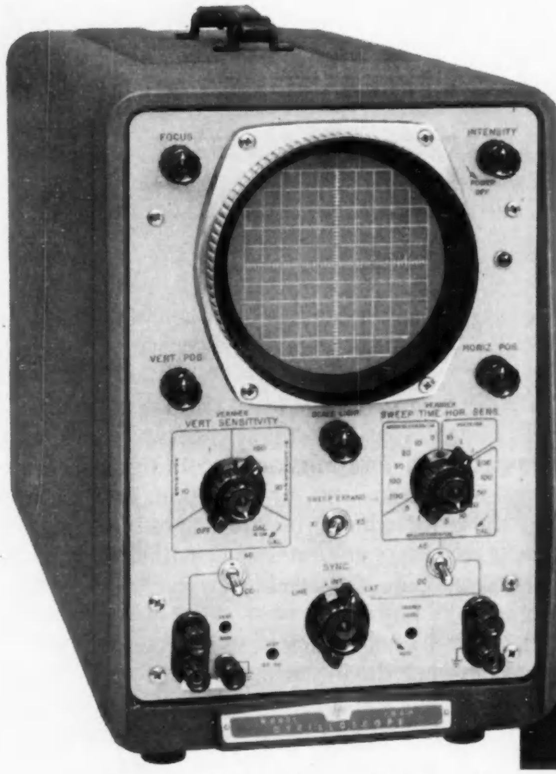
. . . would you write what is printed on pages 65 through 80? That was the question and the challenge. To put on your shoes, see with your eyes, hear with your ears, and ponder with your brain. To fence as you would with Soviet officials for visits to plants and institutes and for exchanges of technical know-how with Soviet engineers and scientists. To ask your questions—about measurement, data transmission, recording, data handling, computation, testing, decision-making, or actuation, and to seek out applications similar to those for which you are responsible—in raw material processing, electrical power generation and distribution, nuclear power, metallurgy, fabrication, machine tools, military vehicles, or control product design and marketing.

It seemed like a tall order; but 13 colleagues from the control field, a technical journalist's dream team, cut the job down to size for me. Each took a topical assignment. With block diagrams, schematics, equations, and hand signals they communicated qualitative information with Soviet engineers. (They missed the chalkboards that are so common in the offices of American control engineers but so rare in the working quarters of their Soviet contemporaries.) Able interpreters maintained quantitative communication and clarified terminology. A battery of American, Japanese, and German cameras (including a Minox equipped with strobe-flash unit), two dictating machines, and scribbling pens recorded a million observations. Written in your vernacular and directed toward your frame of reference, the essence of these observations makes up what I think you would report.

Fourteen American engineers from two technical delegations visited plants and institutes in a trapezoidal area of U.S.S.R. real estate roughly bounded by Leningrad, Moscow, Tula, and Kiev. They were members of the six leading U.S.A. technical societies concerned with control. That the visit took place is extremely important to our technical community, but it has, after all, produced only one set of observations in time and space. This set has a high value now, but isolated, its value will have a short half-life. Its value can grow only if similar visits occur again and again, each one widening our present and future knowledge of U.S.S.R. control technology and our acquaintance with U.S.S.R. control engineers.

W. E. Vannah

All new -hp- oscilloscope 435^{00}



DC to 200 KC coverage; automatic triggering, minimum controls

Sweep speed range 1 µsec/cm to 0.5 sec/cm; x 5 sweep expansion all ranges; vernier

15 calibrated sweeps, 1-2-5 sequence

Automatic synchronizing on any internal or external voltage; also line voltage

High sensitivity, calibrated vertical amplifier

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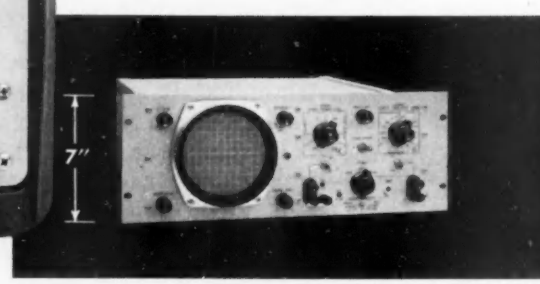

New *-hp-* 120A and *-hp-* 120AR (rack mount) oscilloscopes. Note space-saving 7" height of 120AR.

These totally new *-hp-* oscilloscopes are engineered to perform most oscilloscope measurements more quickly, simply, dependably. Automatic triggering means no adjustment over entire range. Yet automatic trigger and base line can be cut out for bright, steady photography trace.

Sweep speeds vary from slow for mechanical or medical work to high for rapid transients. High sensitivity permits working direct from transducers in many cases. Vertical and horizontal amplifiers have identical band width for phase measurements. Voltage regulation on all power supplies insures steady, drift-free traces.

These new instruments combine calibrated precision for lab work with brute ruggedness for the production line; the rack-mounted 120AR is ideal for fixed installations and test consoles.

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A Team Reports on Control Inside RUSSIA

A CONTROL ENGINEERING SPECIAL REPORT

Moderated by
WILLIAM E. VANNAH, Control Engineering

A 16-day tour of plants and development institutes reveals the startling growth of U.S.S.R.'s control industry, the key part that control application plays in the growth of Soviet basic industries, and the ability of Soviet control engineers to "make-do" with standard products.

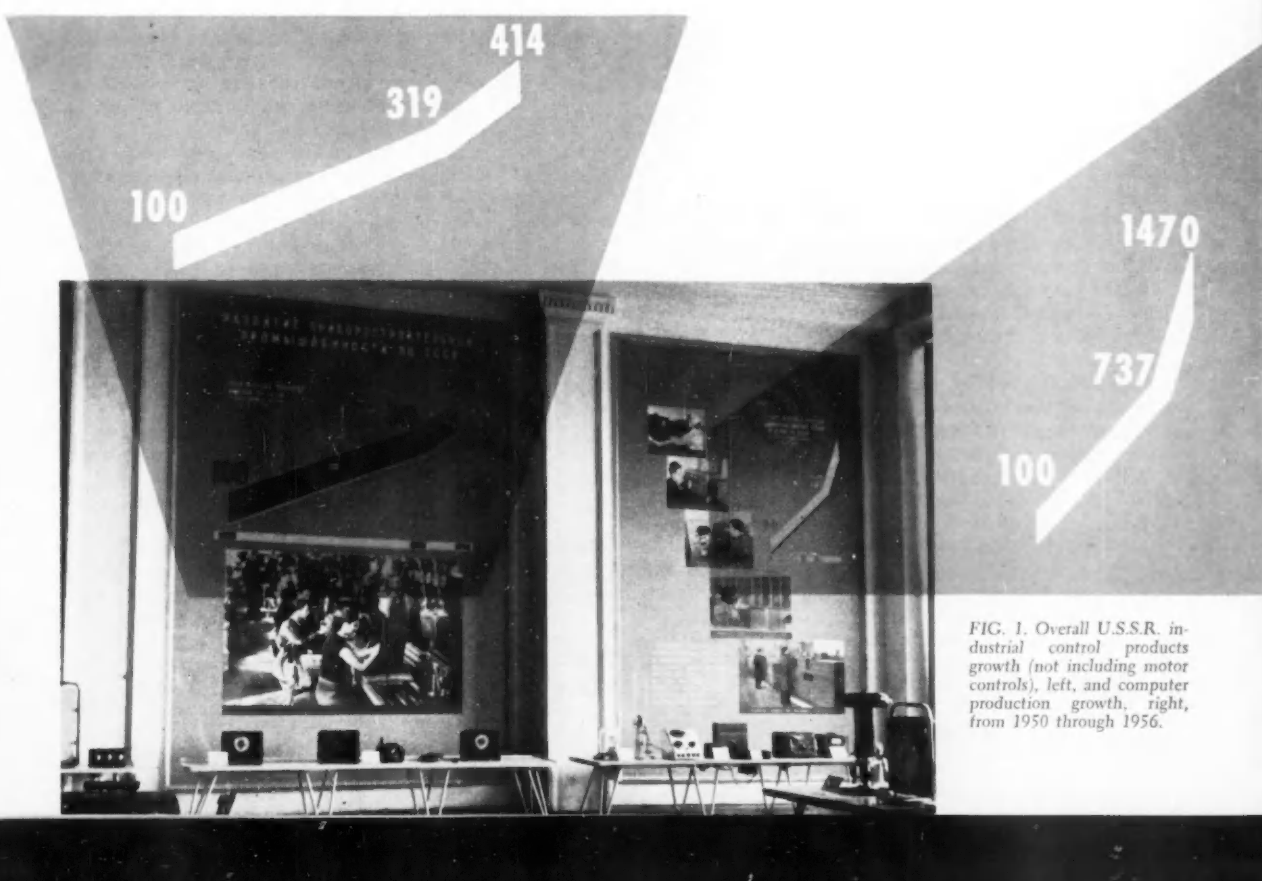


FIG. 1. Overall U.S.S.R. industrial control products growth (not including motor controls), left, and computer production growth, right, from 1950 through 1956.

At side of table: S. W. Herwald, Westinghouse Air Arm; E. J. Kelly, Lincoln Labs; E. M. Grabbe, Thompson-Ramo-Wooldridge; R. L. Palmer, IBM Data Processing Div.; N. Cohn, Leeds & Northrup; P. S. Sprague, Hays Corp. Not shown: G. C. Newton, MIT; R. J. Kochenburger, U. of Conn.; H. W. Ziebolz, General Precision Equipment; H. W. Mergler, Case Institute of Technology.

SETTING

Delegations were the rage in the U.S.S.R. while the 13-man delegation of the American Automatic Control Council was there from Aug. 17 through Sept. 2. Our ingoing flight carried delegate Abdula Whabkan, speaker of the Pakistan House of Parliament, to a congress of parliamentarians. At the Hotel Ukraine in Moscow we met U. S. delegates attending a meeting of the International Astronomical Union at Moscow University. Members of a U. S. target-rifle team were also on hand. A ten-man electrical industry delegation led by Detroit Edison President Walker Cisler, grouped around an American flag on a table in our dining room each time they returned from commuting trips to power stations and electrical machinery manufacturing plants. The luggage of an enormous trade and political delegation from Hungary clogged the usually spacious lobby of our hotel a few days before we left the U.S.S.R. Just ahead of them appeared a four-man American computer delegation invited by the Institute of Precision Mechanics & Computers of the Academy of Science. Norman Scott, whose story appears on page 77 as part of this report to you, was a member.

Officially, we were guests of the Government Scientific & Technical Committee (GSTC), of which Y. Maksarev, a member of the Council of Ministers, is chairman. Unofficially, the Institute of Automatics & Telemechanics of the Academy of Science acted as host from time to time. The lines of separate authority blended somewhat in the latter days of our visit under weight of the obvious advantages of having Institute personnel meet extensively with their opposite numbers in our delegation.

TOUR

Three black limousines, a sight-seeing bus, the "Red Arrow" sleeper train to Leningrad, and two-motored Ilushin return to Moscow provided transportation. Because the team's interests in control cut across basic industry lines, the tour included a wide variety of Soviet enterprises that use, manufacture, or develop control equipment.

Aug.	18	Moscow Steam Plant No. 11
	19	Industrial Exhibit (Machinery & Acad. of Science Pavilions), Moscow
	20	Watch-making plant, Moscow
	21	Moscow Univ., Physical Sciences Dept. Experimental Machine Tool Research Institute (ENIMS)
	22	"ZIL" automotive works, Moscow
	23	Institute for Automatics & Telemechanics (IAT), Moscow
	25	"Vibrator" plant, Leningrad; makes oscillographs and instruments for indicating electrical variables
		Electromechanical plant, Leningrad
	26	"Kinap" plant, Leningrad; makes all forms of cinema equipment
	27	Inst. for Standards & Measures
	28	Tula Metallurgical Combine
	29	Group discussions of control theory, design and application of digital computers, economics of control, and design of control products
	30	"Manometr" plant, Moscow
		Ball bearing plant, Moscow
Sept.	1	Atomic power reactor at Obninsk

FIG. 2. Y. Maksarev, chairman of Government Scientific & Technical Committee (GSTC), his staff, and executives from some of the plants and institutes visited by the American Automatic Control Council (AACC) delegation welcome the delegation on Aug. 18. From map clockwise around right side of table: Y. Maksarev; G. Aleksenko, deputy chairman; K. Stroganov, chief engineer ZIL works; D. Gvishiani, committee foreign relations chief; E. P. Epler, Oak Ridge National Lab; J. Felker, Bell Tel Labs; W. E. Vannah, CONTROL ENGINEERING. Behind Stroganov: V. Karibsky, committee automatics chief; A. Prokopovich, director of Experimental Machine Tool Research Institute. Behind Vannah: A. M. Letov, associate director of Institute of Automatics & Telemechanics.

"Only forward" is the attitude of Soviet technical management, engineers, and technicians. One of our more exuberant escorts on a 16-day tour of Soviet plants and institutes said it. Personnel manning industrial enterprises mean it. Red and white Communistic banners and slogans scream it in factories. Charts and graphs displayed at plants and at the Industrial Exhibit in Moscow demonstrate the forward motion.

The U.S.S.R. turned out 27 million well-made watches in highly mechanized plants last year and expects to increase this output by 6 million this year. It reports a four-to-one increase in overall "instrument" production from 1950 to 1956, according to Figure 1, and it projects an increase of 2.8 times from 1956 through 1960. At the same time it has produced several sputniks. Understanding of the part that control technology plays in an industrial complex that can demonstrate such vigor is essential to western control engineers, for Soviet industrial management now recognizes automatic control as the most significant key to increased production.

U.S.S.R. Central Planning Committee recognition is apparent in the granting of higher production bonuses to the management and engineers of plants producing control products than to their counterparts even in plants as important to Soviet progress as truck and automobile works. This same recognition shows up in the freedom given scientists and engineers at the Institute of Automatics & Telemechanics (IAT) in Moscow to pursue their own special bents in development of theory, components, or applications. And it shows up in arbitrary directives handed down to follow measurement standards policed by the Institutes of Standards, Gages & Metrology. It is clear that control technology is a salient behind which the U.S.S.R. is aligning tremendous manpower, productive capacity, and technical talent. This forced activity is not new to Soviet industry. The electric power, metallurgical, petroleum, and heavy machinery industries have all enjoyed and, at the same time, suffered under it.

Progress to order

Moving "only forward" by directive can cause, and already has caused, some setbacks to Soviet control technology. There is the story, for example, that a directive was issued instructing plants to use radioisotope gaging wherever possible; first, because of the potentially great strides in improved performance of machines and processes fitted with these gaging elements, and second, because the technique was the latest thing. Radioisotope measuring elements were developed to measure tin plate by secondary radiation, linoleum basis weight, cloth web thickness, concentration of solids in dredging pipes, and level of molten steel in the crystallizer of a continuous-pouring slab machine. They worked, but some required gamma sources of such high intensity that they endangered workmen operating the machinery. These measuring elements have been removed and will not be replaced until protective shields can be installed or safer measuring means found. The loss in confidence will not be easily overcome.

Notwithstanding the false starts and, sometimes, overpriming of control application, the trend is toward greater mechanization and more sophisticated control to obtain increased production of guns, butter—and luxuries. To-date, the industries in which control has

been applied most completely are the basic ones that support industry. They fell in the following order when V. Karibsky, automatics chief of the Government Scientific & Technical Committee (GSTC), listed them according to the degree to which he considered them automatic.

1. Power, especially hydroelectric
2. Steel and other metallurgical industries
3. Petroleum refining and production
4. Heavy machinery, especially for automobile and aircraft manufacture
5. Chemical: synthetic rubber, alcohol, and ammonia; plastics and synthetic fibre are just getting started.

The order will shift as production of consumer goods increases, and Karibsky seems quite conscious of the necessity of proving the productive and economic gains offered by mechanization and control in the new industries as well as in the old. However, his facts and techniques for proving out are not as complete as ours (and ours are often sketchy). He indicated that the U.S.S.R. Central Planning Committee favors applications of improved control primarily to reconstructed and new plants. In them the committee keeps one eye on economic payout time (N. N. Elshin of the Government Committee for Chemistry mentioned that two years is considered satisfactory in his industry), but pays much more attention to dramatic increases in production and productivity per man hour. Therefore case studies are reported in these terms. Karibsky offered examples that he considered outstanding. Among them was a doubling of the First State Ball Bearing Factory's (Moscow) output from 1950 to 1956 through mechanizing a series of manual machining and inspection steps; personnel increased by only 8 percent. Another was a 500-ton-per-year saving in basic raw material, ethyl alcohol, at the Efremov Synthetic Rubber Works, through making a series of processes automatic.

Application engineering by bureaucracy

Within the scope of marketing an American control manufacturer includes teaching his customers how to apply and maintain the product. He may include application engineering on new problems. But the U.S.S.R. economic system does not include marketing in the scope of its manufacturer's activities, which means that Russian control makers concentrate on production and assume no responsibility for teaching the customer or for advising him on application engineering. Manufacturer and eventual customer are neatly separated. Marketing of a product line is conducted by a government trading organization. Aside from distributing bulletins and catalogs, it doesn't teach or advise the customer, either. Who, we wondered, does?

We picked up a thread of the answer while talking with Maria Tishchenko, control engineer at Moscow Steam Plant No. 11. She explained that she and the engineering staff at the plant specify and apply control equipment needed for routine replacement and for small-scale changes. But engineers in the Ministry of Power or in special design institutes handle all specification on new construction and major replacements. As for education, since graduating from the Polytechnic Institute of Leningrad in 1938, she has constantly read books and literature on control.

Another thread appeared at the Metallurgical Combine in Tula. There we discussed with Mr. Bulachov, director of the plant, the problem of controlling flow of molten steel from a ladle into the water-cooled crystallizer of a continuous-pouring slab machine similar to a Jones & Laughlin machine. We learned that people from GSTC and IAT had been called in on this problem, first to tackle measurement of the level of molten steel in the crystallizer, and then to design the proper lift characteristic into the control plugs at the bottom of the ladle. Bulachov also confirmed that it was his plant in which A. B. Chelustkin of IAT would have an opportunity to experiment with some ideas for automatic computer optimization of open-hearth combustion products and fuel/air ratio.

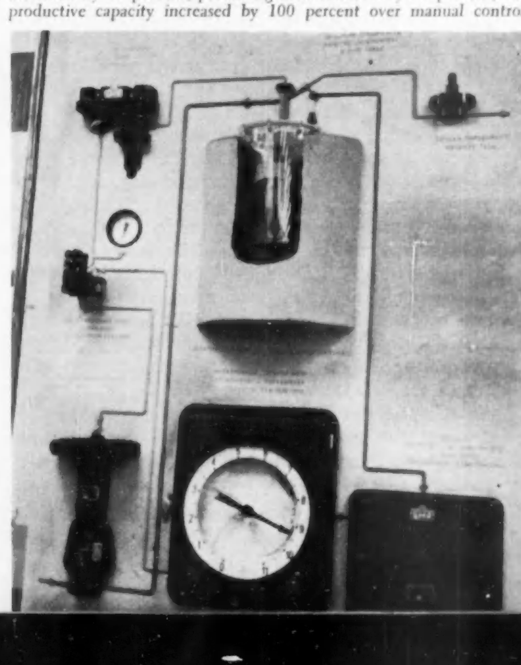
Both threads pointed up into the hierarchies of ministries and committees. To an industry's vertical ministry, if the job of specification and application is not too special. To the horizontal Government Scientific & Technical Committee, or directly to a research and development institute, if the job presents unsolved but fundamental problems. This is a way of pulverizing problems with a lot of high-powered talent, but the stimulus of interplay between customer and manufacturer is lacking.

The GSTC substitutes for the competitive stimulus of our system. This it does by gathering and distributing sound application practices, by taking problems from each of 30 industries and working on them with development institutes, by assigning problems based on its analysis of the U.S.S.R.'s technico-economic needs, by acquainting the trading organizations with equipment needs, and by finding plants in which institute experiments may be run. Through his staff Karibsky maintains contact with 3,000 control people across industry. As he says, he "must be a broad-gage, gray-haired man".

Standards with teeth

Equally intermingled with plants and bureaus is the All-Union Institute of Standards, Gages & Metrology.

FIG. 3. System automatically selects the maximum of temperatures in three zones of titanium reactor and then maintains this temperature and reactor top pressure at a preset ratio by manipulating the flow of feed slurry. Claims stated: productivity per man-hour increased by 30 percent, processing time reduced by 70 percent, and productive capacity increased by 100 percent over manual control.



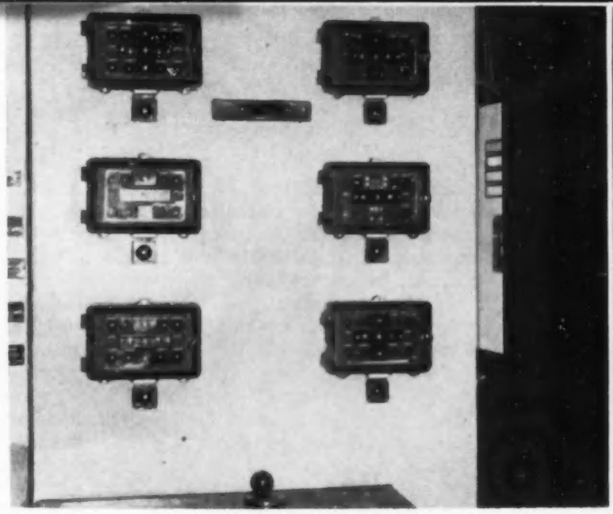


FIG. 4. A system of electronic controllers installed five years ago at Moscow Steam Plant No. 11 controls (counterclockwise from upper left) feedwater flow, fuel flow, furnace draft, air flow, first water spray valve for superheat temperature, and second water spray valve automatically balanced with first.

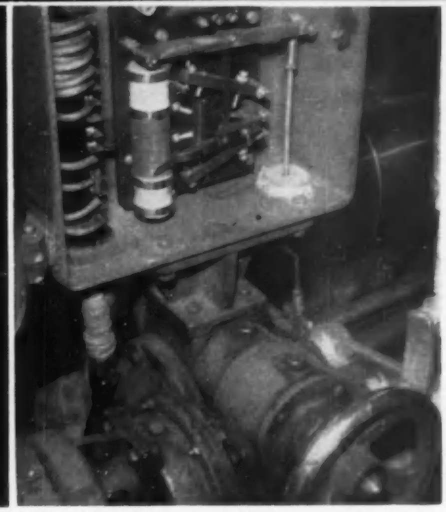
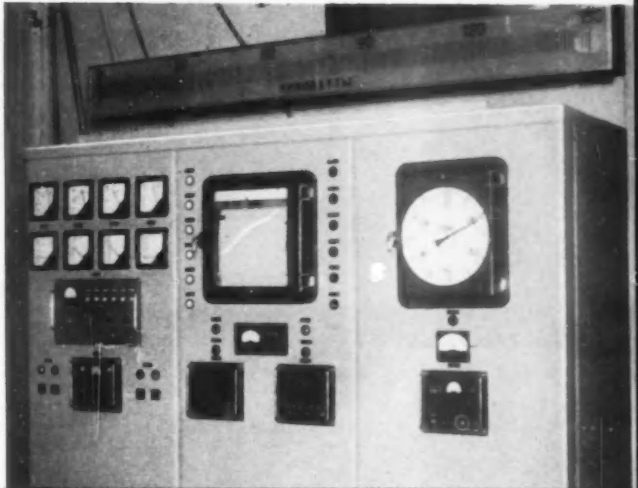


FIG. 5. Electric drive unit with characterized cam feedback through slidewire rotates butterfly valve in accordance with electronic signal from draft controller shown in Figure 4.

FIG. 6. Electronic instrument panel for demonstration nuclear reactor built in 1955. (Note giant-size light-beam galvanometer that indicates killowatts.)



From its headquarters in Leningrad it directs the enforcement of dimensional, weight, pressure, and flow standards to which products must be made. It publishes standards and a transactions. In Moscow, as in each major economic region, a branch maintains standards, tests new measuring instruments with potentially wide use and at least twice annually makes unannounced inspections of instrument manufacturers' products. Mr. Karelin, director of the Moscow branch, stated that plant managers are subject to court action if discovered not adhering to the standards. He showed us:

- optical instruments for measuring surface irregularities down to $\frac{1}{2}$ micron within 1/300 micron
- a dead weight tester balanced against a water column for checking pneumatic transmitters
- a hydraulic device for measuring mass to within 0.005 percent
- construction of a new liquid flow laboratory for testing orifice-type, electromagnetic, and Corealis-type meters.

The Institute has not yet endorsed electromagnetic flowmeters, further confirming that those seen at the Industrial Exhibit are prototypes.

All control media have champions

As in the U.S., electronics is the most rapidly growing medium for industrial control, though pneumatics and hydraulics are very much in the race. Dr. M. A. Aizerman of the IAT believes that while pneumatics has been thoroughly exploited for transmission, control function generation, and actuation, possibilities for their use in computing control have been overlooked. To demonstrate his contention he has built:

- a pneumatic extremum controller that can find and maintain an optimum relationship between two variables (similar in function to the Quarie controller)
- match-sized pneumatic logic elements that operate on an aerodynamic jet principle and moreover have the advantage of containing no moving parts

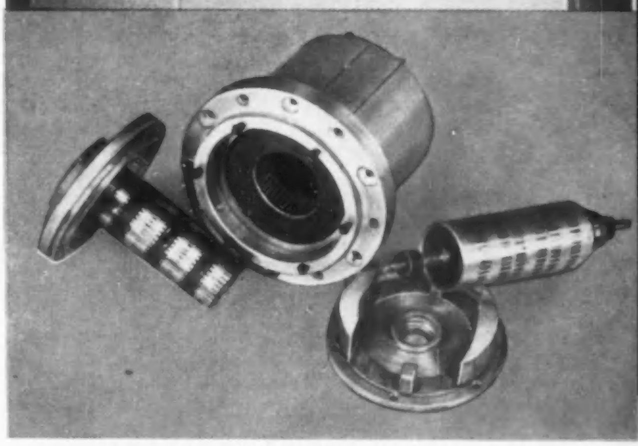


FIG. 7. Disassembled fractional horsepower stepping motor that positions the pilot of a rotary hydraulic servo used on an ENIMS machine tool.

The latter will be described later in CONTROL ENGINEERING. *Ed.*

U.S.S.R. petroleum, chemical, and nonferrous metal processing plants use pneumatics extensively (there are reports that the National Fire Dept. has so far opposed electronic instrumentation in chemical and petroleum plants). Visitors to the Automation Exhibit in New York last June may have seen some of the Soviet stacked-diaphragm pneumatic controllers. Figure 3 shows an arrangement, including one for controlling a titanium reactor. But in steam-generating electric power plants, energized both by combustion and by nuclear fission, in steel mills, and on machine tools, electronic controls are overwhelmingly in use. Dr. Aizerman may well be on an important track with his pneumatic logic elements, but those displayed at the Industrial Exhibit are electronic (printed wire and static components). Figures 4, 5, 6 and 7 show systems and system components used industrially.

FIG. 8. Display on central bulletin board of Moscow's "Manometr" plant hails two design innovations. Left: high-sensitivity amplifier and power supply for electronic recorders and indicators; stated annual resulting economy—1,184,000 rubles. Right: high-pressure rotameter with core-and-coil pickup; stated annual resulting economy —438,000 rubles.

Life is beautiful now

Russian control engineers are technically capable, competitive, and certain that they are achieving a degree of material success never enjoyed by their predecessors. "Life is beautiful today," often repeated by C. Bolchakov, our constant escort from GSTC, expresses their conviction. A student starts with a basic science education in the university (or basic engineering in a technical institute), which costs him nothing if his marks are high. Faculty and equipment are good. When this work is completed, the student receives the title of scientific worker or teacher (in a technical institute he gets the title engineer). Only those who take post graduate work earn higher degrees. After three years of advanced academic study, along with some practical work in the field, the student plans a thesis or dissertation. When this is completed and accepted by two-thirds of the members of a board of review, he is awarded the degree of candidate of science. In exceptional cases where the dissertation has been unusually scholarly, the student may be awarded a doctor's degree. Usually, however, to win the doctorate, a student must prepare a second dissertation (he takes no additional course work). After successfully defending this dissertation, he is awarded the degree of doctor of physics and mathematics, or of engineering or of science.

Moscow University's physics faculty, as an example, teaches basic science and numbers 300 instructors, 40 to 50 of whom are professors. The student body of the Physics Sciences consists of 3,000 undergraduates and 300 graduates completing their classroom studies for the candidate of science degree. Candidates may do their thesis work at institutes such as IAT or while tackling new problems as plant employees.

Laboratories in institutes and plants are crowded and equipped with a conglomeration of electronic and mechanical apparatus, but the apparatus works and its users produce adequate designs. Each bureau and economic region draws extra effort out of the engineer and urges him to exceed the limitations of his laboratory by awarding generous bonuses for innovations. Innovation bonuses for engineers average 5,000 to 10,000 rubles and can go as high as 50,000 rubles (8 to 10 rubles have the purchasing power of a dollar). Two innovations developed by instrument designers at the "Manometr" plant (Moscow), manufacturer of process flowmeters, recorders, and indicators, are shown in Figure 8. Their innovators earned awards in the 50,000-ruble bracket.

A control engineer from a petroleum refinery in Baku seen reading a book on cybernetics on a Moscow subway car demonstrated the intense desire of Soviet engineers to learn. And well they might, for the benefits and prestige awarded competent engineers put them well up on the social and economic ladder. Engineers and scientists such as those at IAT own country houses outside Moscow, even if they don't own the land on which the houses are built. Those who have winterized their country houses (as Chelustkin of IAT has) for the day when natural gas becomes available for heating will form Moscow's first wave of exurbanites. Vacations, time off for technical teaching, and time off for independent research are all scaled to the engineer's technical standing. Some of the IAT staff have six weeks' vacation per year. A. M. Petrovsky takes a day per week from his duties at the Institute to teach information theory. Dr. A. M. Letov, anxious to be free of his administrative duties as associate director, looks forward to the time when he will be granted two days per week to work at his country house on abstract mathematics of nonlinear control system stability.

That a young engineer would read about cybernetics on the subway while on holiday in Moscow, that the Academy of Science bookstore on Gorki Street in downtown Moscow would be crowded on Sunday (all stores are open then), that the GSTC would arrange for rapid offset reprinting (U.S.S.R. does not recognize the international copyright convention) of complete issues of foreign engineering journals such as those shown in Figure 20, are all not surprising when one considers the incentives for the Soviet technical man. Or when one considers the leap that Soviet technology has made into the modern technical world by appropriating technical information owned (in our sense of the word) by others.

1 Development of Theory and New Components

G. C. NEWTON, MIT
R. J. KOCHENBURGER, University of Connecticut

R. J. Kochenburger has mixed control theory with hardware since he graduated from MIT with a BSEE (1940) and MSEE (1941). He spent five years at Curtiss Wright as a research engineer, ultimately became head of the analytic group in the Propeller Div. In 1946, when he returned to MIT to study for his doctorate, he introduced the use of describing-function theory for handling nonlinear systems. Since 1951 he has been on the faculty of the University of Connecticut, where he is now a full professor of electrical engineering.

G. C. Newton Jr. has developed control systems using servomechanism, radar systems, and computers at Sperry Gyroscope Co., Inc. (now a division of Sperry Rand Corp.), the U.S. Navy's Special Ordnance Plant, and MIT. Holder of several patents for control hardware, Newton won the Franklin Institute's Levy Medal in 1953. He received his ScD degree in electrical engineering from MIT in 1950; is now a member of the faculty. His title: associate professor of electrical engineering and associate director of the Servomechanisms Laboratory.

Most basic Soviet control developments are accomplished in institutes of automatics and telemechanics located in major U.S.S.R. cities, such as Moscow, Leningrad, and Novosibirsk. Fortunately, the delegation was able to visit the Moscow institute, the one with the highest international reputation and source of the journal, *Automatics and Telemechanics*. When asked what areas they considered most important, staff members' answers revealed their specialties:

- A. M. Letov, stability of nonlinear control systems
- A. M. Petrovsky, application of information theory to control
- M. A. Aizerman, design of control systems subject to logical limits, control theory employing algorithms based on difference equation analysis, and transmission of random signals through nonlinear elements
- V. S. Pugachev, analysis of systems subjected to stochastic disturbances (using canonical expansions with orthogonal random coefficients to represent the stochastic signals)
- Y. Z. Tsypkin, sampled and quantized data systems
- A. A. Feldbaum, adaptive and extremum controllers
- B. N. Naumov, transient responses of linear, time-varying, and nonlinear control systems.

Asked what applications they had found for nonlinear control theory, Dr. Letov mentioned optimum design of switching-type controllers and Dr. Aizerman referred nonspecifically to optimizing or extremum controllers. No actual industrial applications were cited, although V. Karibsky indicated that CSTC stood ready to conduct experiments. A. M. Petrovsky answered an open question on application of information theory to control by discussing a problem in which noise limits system stability and performance. The problem arose in the centralized control of electric power systems in response to data transmitted over long transmission lines. (See page 22 for a mention of his solution, presented at the Instrument Society of America meeting in Philadelphia, Sept. 19.)

Analog computers for digital systems

On a tour of his laboratory, Dr. Tsypkin displayed analog simulators used to study discontinuous control processes. The equipment included an EMY-8A, designed by IAT personnel and shown in Figure 9. It uses a quarter-squared multiplier, said by its designers to have as high an accuracy as one using any other method, including pulse-width modulation. The quarter-squared method, they also claim, requires less-involved electronics and simpler maintenance. The analog is just now going into limited production.

Also in Dr. Tsypkin's laboratory was a 1-microsec delay line used to simulate delay time in a manner disclosed in 1951 by J. M. L. Janssen and L. Ensing of The Netherlands.

Dr. Aizerman, while showing his pneumatic and hydraulic laboratory, claimed accuracies of plus or minus ¼ percent for wafer-shaped pneumatic adders, integrators, and square-root extractors (they contain no moving parts) that he exhibited in addition to the logic elements mentioned earlier in this report. He admitted that his pneumatic devices do not have the computing speed of electronic ones, but he argued that their ruggedness, insensitivity to vibration, thermal stability, and lack of fire hazard would make them attractive industrially.

The institute's function is described as the solution of basic problems in control, but the word "basic" appears to apply to components, equipment, and applications, as well as to theory. The laboratories inspected and the contents of the institute's monthly journal support this impression, although industrial application receives light emphasis. Top research people seem quite free to pursue the lines of research that appeal to them and there is no apparent pressure to reach immediate objectives. They reported little difficulty in obtaining funds necessary to pursue their research, and although the Soviet Union suffers from a shortage of skilled technicians, no such shortage exists at the institute.

FIG. 9. EMY-8A analog is composed of modules containing four blocks each—a linear coefficient unit with an open loop gain of 10^6 up to 10 kc, a quarter-squared multiplier with a plus or minus 1 percent accuracy over the same frequency band, a function fitter, and a sinusoidal function generator.

2 Machine Tool Control Developments

H. W. MERGLER, Case Institute of Technology
G. C. NEWTON, MIT

H. W. Mergler has been interested in machine tool control since 1951, when he first experimentally controlled a milling machine with an analog computer at the National Advisory Committee for Aeronautics Laboratory. He earned his BS, MS and PhD degrees from Case Institute of Technology and worked for eight years as a computer and control scientist at NACA. He is now assistant professor of mechanical engineering at Case and a consultant to machine tool builders.

A. Prokopovich, director of the Experimental Machine Tool Research Institute (ENIMS), Moscow, gave two convincing pieces of evidence to support his belief that no contemporary machine design can exclude automatic control. First was the institute's version of the ubiquitous Soviet growth chart, showing a continuing 8/1 growth of completely automatic tools in the last 10 years while mechanized tools have slowed to a 5/1 growth. Second was his statement that one-third of the institute's professional staff was conducting research and development directly related to control.

Machines and their control system components inspected at ENIMS and at the Industrial Exhibit show that the Soviets are making full use of information available from U.S. and U.K.:

- a completely automatic crankshaft balancing machine that measures angular position and magnitude of dynamic unbalance, stores the data in an electromechanical memory and transfers the workpiece to a drilling station that removes an automatically calculated amount of metal
- a horizontal boring mill built in 1957 with three controlled axes, operating as a pulsed data system with incremental logic. Commands for the three controlled axes are stored on a six-channel magnetic tape about 35 mm wide. Quantum size was 0.02 mm per pulse, stored at a maximum density of six pulses per mm at a tape speed of 200 mm per sec. Rotary digital transducers mounted directly on the machine's lead screws generated 524 pulses per revolution, through photodiode sensing. Conventional two-brush logic provided phase detection. Servomotor (1,700 watts dc) powered by rotary amplifiers drove ball-screws shown in Figure 10 with double, preloaded nuts. Maximum speed of the power servos was 850 mm per min.
- a point-to-point jig borer built in Odessa. Telephone dials set 24 points in two coordinates. Controlled by stepping switches, an 80-watt stepping motor, see Figure 7, piloted an hydraulic power servo.
- a tool programmed with punched paper tape, quantized by a linear electromagnetic transducer with a 0.1 mm pitch, and powered through the electrohydraulic valve shown in Figure 11.
- 4½ x 7 panel plug-in pulse circuitry using the Russian P6A and P6B transistors. Characteristics of the П 6 Г, a transistor in the same series, are stated in Table I.

Some general conclusions:

- **technical developments lag those of U. S. and U. K., particularly in analog-to-digital transducers (no admitted effort at absolute encoders) and low performance power servos.**
- **because coding of the commands on secondary storage media (punched or magnetic tape) yields no clues to the techniques of generating programs, it is impossible to evaluate the technical level of the Soviets' manipulative circuitry or their numerical interpolation techniques, although the URAL computer was used to compute interpolations for the three-axis machine.**

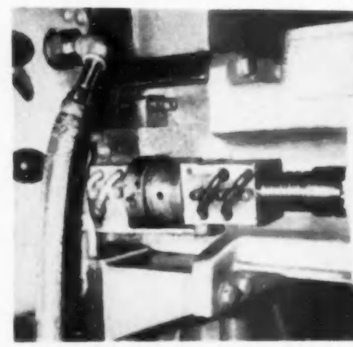


FIG. 10. All new designs of Soviet machine tools with lead screws incorporate ball screws that are rolled, hardened, and then ground with equipment such as that manufactured by the Churchill Machine Tool Co. in England.

FIG. 11. Because of the low (150 psi) working pressure of this push-pull electrohydraulic valve, the valve is bulky and the cylinders that actuate the machine tool table have a large bore (120 mm).

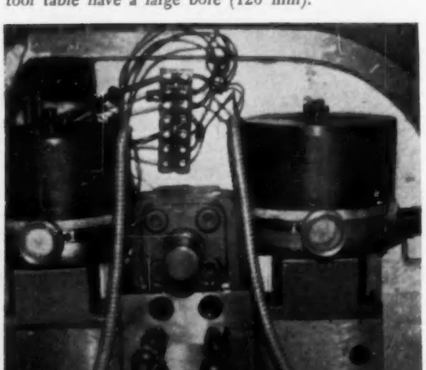


Table I. Stated Characteristics of Two U. S. S. R. Transistors

	П4Д	П6Г
Max emitter current	3 a	10 ma
Max emitter voltage	−50 v	
Max emitter switching current		50 ma
Reverse emitter current	0.4 ma	
Grounded base input impedance		40 ohms
Grounded base reverse voltage transfer ratio		4×10^{-4}
Grounded base (forward) current transfer ratio	20 common emitter	0.98 common base
Grounded base output admittance		1 micromho
Max load	25 w	150 milliwatts
Power gain	30 db	40 db
Alpha cut-off frequency		1 to 2.5 Mc
°C rise/milliwatt		0.5
Max emitter temperature	90 deg C	100 deg C
Emitter capacity		40 pica farads

3 Industrial Instrument Design and Production

NATHAN COHN, Leeds & Northrup Co.

N. Cohn has specialized in instrumentation and control for the process industries since he joined Leeds & Northrup Co. in 1927. A graduate of MIT (1927), Nat holds patents on basic computing and control circuits for area-wide generation control. He has authored a number of technical papers on automatic control and interconnected area electric power systems. He is now manager of Leeds & Northrup's Market Development Div.

Statistics displayed at the Industrial Exhibit in Moscow indicate that while U.S.S.R. electric generating capacity has almost quadrupled in the last 16 years, and steel production has tripled in 10 years, the production of *industrial* measurement and control instruments has increased almost *five-fold in the last six years.* Industrial instrumentation seems to be, therefore, the fastest growing field in the U.S.S.R. While we could not substantiate this growth, our observations in plants indicated that a competent U.S.S.R. instrument industry had developed, essentially from scratch, since the early 1930's.

We saw many examples of dial-type laboratory precision resistance decades, Wheatstone bridges, Kelvin bridges, and precision potentiometers, as well as portable bridges and potentiometers. Designs were strongly reminiscent of American designs. A few of the dial-type instruments used switching contact designs normally associated with German precision apparatus. In ac gear we saw signal generators, frequency meters, oscillographs, electronic test sets, and comparable apparatus similar in appearance to equipment manufactured in this country. Figure 12 shows an eight-channel oscillograph on which the "Vibrator" plant in Leningrad has a U.S.S.R. monopoly. Not all units were copies, and the Russians were proud of design advances—from their point of view—of their own. For example, at the "Vibrator" plant we were shown calibrated deflection-type lamp and scale meters using suspension movements, for which high sensitivity and stability were claimed. This technique has found little favor or usage in the U.S.

In process instrumentation the U.S.S.R. produces large strip-chart and round-chart electronic self-balancing bridges and potentiometers (Figure 16). The strip-chart instruments are both single- and multiple-point, with automatic potentiometer standardization and the usual variations of contacts and accessories. The round-chart instruments, of which we saw three different versions, had semi-automatic potentiometer standardization. Round-chart and miniature electronic strip-chart recorders are available not only with servo-driven slidewire balancing units, but with core-and-coil balancing units for use with core-and-coil flow and pressure transmitters. Figure 13 shows the minature recorder.

Launched from American designs

In creating their own industrial instrument industry, the Soviet engineers borrowed liberally from the work of others—principally American recorder-controller manufacturers. Nevertheless, Soviet engineers emphasize that they have made, and are continuing to make, many important innovations of their own. For example, they have a great interest in the development of new techniques of flow-metering. They are particularly proud of a new design of a diaphragm differential pressure transmitter, Figure 14, built at the "Manometr" plant and for which they claim operating and over-range protection features superior to those of other available flowmeters.

We also saw some interesting variations of self-balancing measuring units which were, as far as my knowledge goes, new—in packaging and geometry. These included:

- a 12-point scanning system, the automatic switch located behind the front door of a round-scale self-balancing potentiometer and a large dial mounted within the temperature indicating dial and linked to the automatic switch to indicate the alarm point.
- a circular dial servo indicator in a 6-in. case, with geared settings for con-

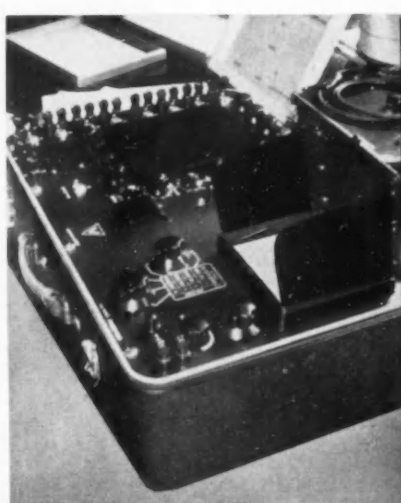


FIG. 12. Monopoly product of "Vibrator" plant is eight-channel oscillograph. Plant makes 3,800 per month.

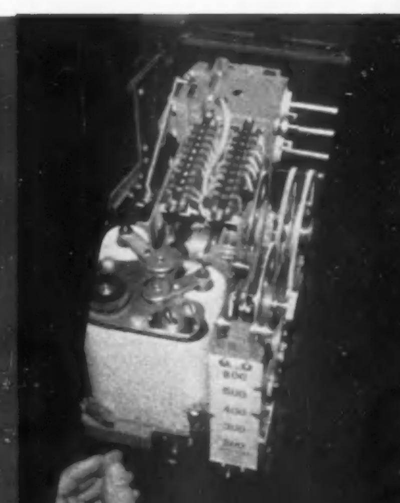


FIG. 13. Miniature electronic recorder has core-and-coil balancing unit, rear, and adjustable alarm contacts set by gears at right.

centric pointers tied to high and low adjustable contacts
• a neatly packaged drum-type self-balancing indicator with built-in push-button switches in a small case
• a multiple-revolution self-balancing unit with both "hour" and "minute" hands for indicating thickness of continuous sheets.

And now analysis instruments

Prototype analysis instrumentation was plentiful at the Industrial Exhibit. Included were conventional pH and electrolytical conductivity apparatus, a laboratory pH meter with an electronic detector, and a portable conductivity meter similarly equipped. There were thermal gas analysis assemblies for various measurements, including 80-100 percent hydrogen in nitrogen, and 0-25 percent ammonia. There was a 66-71 percent sulfuric acid specific gravity recorder actuated by bubble-tube back pressure.

There were 0–5 and 0–10 percent O_2 recorders using the paramagnetic method. Later, we saw such recorders in use at the Tula Metallurgical Combine on open hearth and blast furnace control panels. There were also infrared apparatus, one with a range of 0–1 percent methane, but we were informed that these were experimental prototypes and we were not permitted to examine the insides of the analysis cabinets.

We saw an assembly for measuring 10–100 percent relative humidity using wet and dry bulb resistance thermometers and a self-balancing computing circuit, originally developed in this country in the 1920's. In the Analysis Instrument Section, there was a double-range moisture content re-

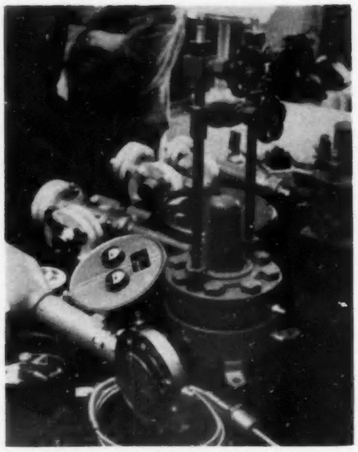


FIG. 14. Differential pressure unit, right center, has core-and-coil pickup and novel self-supporting collapsed-diaphragm element.

corder with a porous Ebonite detector, with overlapping ranges of 0–2 and 1½ to 5 grams per cc.

Electric power instrumentation

Combustion control is all-electric. Figure 5 shows the type of drive unit and Figure 4 an array of electronic boiler controllers at Moscow Steam Plant No. 11. At the Industrial Exhibit two displays of automatic generation control of interconnected power systems were particularly interesting to me. Both are experimental; neither has yet been actually installed. One display showed a method of transmitting an incremental cost rate from a centralized dispatching office to various stations and there automatically computing and controlling individual generator output to match this transmitted incremental cost. Plugboards at each unit established the incremental cost curve for that unit.

The second display, shown in Figure 15, illustrated a cam-type "desired generation" computation at a centralized dispatching office and individual "desired generation" computation and control at each individual station. By our standards this system is cumbersome and inflexible.

At the 5,000-kw atomic power plant at Obninsk, the instrumentation included many self-balancing indicating recorders. In addition, we noted centralized scanning systems with interesting geometric configurations of unit off-normal alarm displays for the temperatures, pressures, and flows associated with the fuel rods in the reactor.

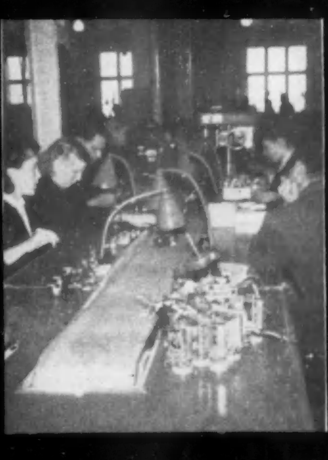
Instruments on a production line

The most outstanding phase of instrument production we saw was the mechanized production line for recorders and indicators at the "Manometr" plant in Moscow. Figure 16 shows views of the line. The complete line, including testing facilities, occupies an area of 100 ft by 100 ft. There are 48 operating stations, not all of which are used for producing every type of instrument. Forty-two of the stations on the main assembly line were in use on the day we inspected it. About 15 percent of the personnel, we were told, were engaged in inspection for quality and accuracy. The production line moves one step forward at 4 min intervals to produce 100 recorders per shift (only one shift per day, because the mechanical shop cannot keep up with the line). During our visit the line was producing large round-chart self-balancing potentiome-

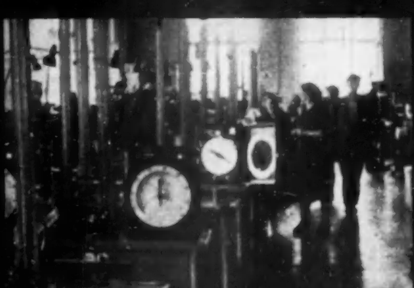
FIG. 16. Assembly line at "Manometr" plant produces round-chart indicators, and controllers and strip-chart recorders, with 1,040 different scales.

Near start, installing power supplies

Chart drives are assembled on feeder line



Instruments are tested alongside line.



ters with semi-automatic standardizers.

The Soviets have made a considerable advance in establishing production plants for industrial instrumentation and in undertaking industrial applications of this equipment. They are now behind us in many aspects of sophisticated industrial instrumentation, in analysis instrumentation, in highly specialized data acquisition systems, and in certain facets of sophisticated application of control systems.

There is, however, little room on our part for complacency.

But neither is there need on our part for excessive alarm. There is simply the obvious challenge to keep our own instrumentation moving forward—as it has been—at a sufficiently high rate so that though the Russians move rapidly themselves, they may not overtake us.

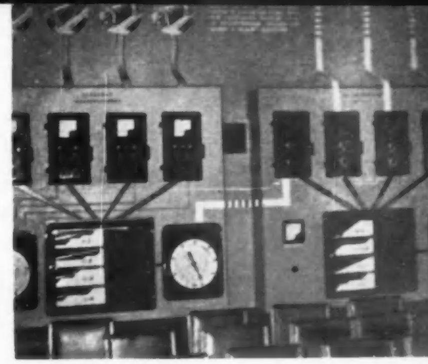


FIG. 15. Prototype cam-programmed control for electric power generation.

4 Steel Plant Measurement and Control

NATHAN COHN, Leeds & Northrup Co.
H. W. ZIEBOLZ, General Precision Equipt. Corp.

H. W. Ziebolz has followed the application and design of hydraulic, pneumatic and electric components for industrial control for the Askania Regulator Co.—now GPE Controls—since 1928. After graduating from Breslaw Technical Institute (masters in ME, 1926), he studied in the U.S. as an industrial postgraduate exchange student, then joined Askaniawerke in Berlin in 1928. He came to the U.S. in 1931 as manager of American Askania Corp. He is assistant to the V-P of engineering, General Precision Equipment Corp.

Seen at the Industrial Exhibit were two interesting control systems: one for blast furnaces and another for open hearths. Later we saw comparable systems in operation at the Tula Metallurgical Combine. The blast furnace system handles automatic control of moisture content of the air blast by manipulating steam injection, hot blast temperature, stove temperature, and dome pressure. As an example of application success, it was reported that 38 of the 50 blast furnaces in the Ukraine have been equipped with similar systems. Users of this system have claimed a 2 percent reduction in fuel consumption and a 10 percent increase in production. The air blast moisture control loop used the relative humidity device mentioned in the previous section, but with the temperature of the air sample held to a constant value so that the moisture reading would be in absolute humidity units. A similar method was discarded in the U.S. years ago due to the difficulty of keeping the wet-bulb wick clean and active.

The open hearth control system regulates: draft, O_2 enrichment flow, air flow, blast furnace gas flow, coke oven gas flow, oil flow, checker temperatures and reversal on either a time or a temperature difference signal.

Nathan Cohn

Tula Metallurgical Combine is interesting in itself, for it serves as a full-scale laboratory from which the steel industry can evaluate new processes and systems. It also produces steel, while permitting the researcher to carefully plan and conduct his experiments without endangering production or quality schedules. Experiments in oxygen enrichment conducted here have produced 50 to 80 percent increases in ferro-manganese iron production and 20 percent reduction in coke consumption by adding 30 to 34 percent oxygen to air blast. Consequently, the new seven-year plan for the steel industry calls for 40 percent of all steel production to use oxygen enrichment, not only in blast furnaces but in open hearths and Bessemer converters as well. Management of the combine acknowledged the decisive role of automatic control in the art of making steel. It pointed to O_2 enrichment controls, conventional hydraulic-jet regulators for stove combustion, and the usual CO_2, temperature, flow, and pressure recorders typical of blast furnace operation.

Discussion revealed the use of immersion thermometers in the open hearths and O_2 analyzers for flue gas. The Soviets are familiar with work done in the U. S. on open-hearth combustion control in direct response to such analyzers. But, preferring not to rely on this direct control, they intend to use the O_2 analysis signal in a supervisory feedforward path to minimize disturbances before they can reach the furnace.

A continuous slab casting machine featured an abundance of strip-chart temperature recorders, which is understandable, since it is an experimental machine. A weighing device will be tried next for measuring the level of molten metal in the crystallizer, now that the radioisotope level instrument has been set aside as too dangerous.

An engineer responsible for overall planning of control systems for the Soviet steel industry expressed emphatically his preference for all-electrical control. His reasons were that installation was simpler, existing electricians could handle maintenance, the system did not need air processing equipment, and experience gained with electrical control (see remarks on Moscow Steam Plant No. 11) demonstrated its reliability. He pointed to the success of electrical control apparatus built by Schoppe & Faeser and Siemens to support his argument. According to him, the combination of hydraulics and electronics is logical for high power levels.

H. W. Ziebolz.
General Precision Equipt. Corp.

5 Control of Nuclear Power Reactors

W. E. VANNAH, Control Engineering
(From discussions with E. P. Epler, Oak Ridge National Lab.)

E. P. Epler has worked on nuclear reactor control problems since 1947, when he joined the staff of the Oak Ridge National Laboratory. Since 1952 he has headed the Reactor Controls Dept. of the laboratory's Instrumentation & Controls Div. From 1943 to 1947 he was engaged in the instrumentation of the Y-12 electromagnetic plant for separating the isotopes, U^{235} and U^{238}. He graduated from the University of Illinois in 1925 with a BSEE and served with the TVA from 1934 until 1943.

A visit to the 5,000 kw (electrical output) power reactor of the Directorate for the Utilization of Atomic Energy, and inspection of the 10-kw demonstration reactor at the Industrial Exhibit are the bases of our comments on nuclear reactor control in the U.S.S.R.

The demonstration reactor differs materially from the U. S. Geneva Reactor (on display at the 1955 Geneva Conference) only in its control system. Table II compares the control systems of the U.S.S.R. and U. S. reactors. Note that the Soviet demonstration reactor uses no artificial source and relies entirely on spontaneous fission of the U^{235} plus the photo neutrons resulting from the D_2O present in normal water. Both the U. S. and the Soviet reactors were drastically limited in fuel loading so that it was virtually impossible for an accidental nuclear excursion to occur. In addition to this the U. S. reactor was equipped with a full complement of low level logarithmic instrumentation plus three independent safety channels. The Soviet reactor had a single counter channel for low level instrumentation and a single ionization chamber for safety.

Completed in 1954, the 5,000-kw power reactor, at Obninsk, is water cooled and graphite moderated. Fuel, uranium alloy enriched to 5 percent U^{235}, is contained in 128 fuel elements placed vertically in the graphite stack. A fuel element consists of a bundle of five stainless steel tubes, each approximately 1.5 cm in diameter and contained in a can 6.5 cm in diameter. Cooling water at 20 atmospheres pressure flows downward through the central tube, divides, and returns upward through the tubes containing fuel.

Impairment of coolant flow in any one channel will cause the channel to burn out, flooding the graphite structure with contaminated water. Flow monitoring in each of the 128 channels minimizes the likelihood of such an accident, for a high flow signal due to increased flow in the ruptured channel shuts down the reactor. In addition, the outlet temperature of each channel is monitored, and nitrogen pressure is monitored to detect slow leaks. Banks of electronic instruments indicate the flows. High and low limit flow and temperature conditions are displayed and annunciated from 3-ft diameter panels with 128 unit indicators. Telephone stepping relays scan each flow at the rate of 128 per 20 sec. Temperatures are displayed similarly but are not scanned.

Figure 17 shows the central unit of the room-wide instrument panel. The safety system releases the two safety rods and motors drive the manually operated rods. The rod system serves primarily to program the reduction of power. Protection is afforded by the fuel and moderator negative temperature coefficients of reactivity.

It has not been the practice in the U. S. to employ only two safety rods when a total of 20 rods are available for fast release. It is true that the strong negative temperature coefficient of reactivity is a large safety factor, but few U. S. builders will place so much dependence on this, in spite of the use of containment vessels.

In recognition of the possibility of fuel element failure, the Soviets have chosen to detect, isolate, and remove the defective element in spite of the very large amount of instrumentation which must perform dependably. In U. S. water cooled reactors such problems are met by designing the reactor so as to minimize the probability of failure and, at the same time, to minimize the consequence of failure.

FIG. 17. Indicators at center of reactor control-room panel show the position of each of 18 manual control rods. Note, too, the graphic display of pump valve conditions.

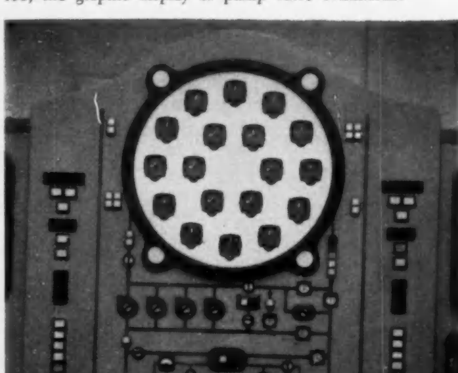


TABLE II.
Comparison of control systems of Soviet Industrial Exhibit Reactor and U. S. Geneva Reactor

	S.U.	U.S.	
Independent safety instrument channels	1	3	
Logarithmic intermediate range instrument channels	0	1	(with
Counter channels	1	2	period)
Servo channel	1	1	
Automatic start	No	Yes	

6 Digital Computers for Business and Industry

NORMAN R. SCOTT, University of Michigan

N. R. Scott has studied electronic computers since he joined the faculty of the Electrical Engineering Dept. of the University of Michigan. Having earned his BS and MS in EE at MIT, Scott served as project officer in the Electronics Laboratory at Wright Field, ultimately became chief of the Special Projects Laboratory. After the war he earned his doctorate at the University of Illinois. He is now an associate professor at the University of Michigan, in charge of graduate courses in computer engineering (analog and digital).

Overlapping the visit of the AACC delegation was a visit by a group of four digital computer specialists: John W. Carr III, associate professor of mathematics, University of Michigan; Alan J. Perlis, associate professor of mathematics, Carnegie Institute of Technology; James E. Robertson, research associate professor of electrical engineering, University of Illinois; and Norman R. Scott, professor of electrical engineering, University of Michigan. As guests of the Soviet Academy of Sciences, this group visited Moscow, Kiev, and Leningrad, delivering lectures on American computer work, inspecting Russian computers, and discussing programming and computer design with Soviet mathematicians and engineers.

They saw the following computers: BESM I, at the Institute for Exact Mechanics & Computing Technique in Moscow; Strela, Ural, and BESM II (under construction) at the Computing Center of the Academy of Sciences in Moscow; another Strela at Moscow University; a machine called Setun being built at Moscow University; another Ural at Leningrad University; two older machines, one a relay machine and the other almost a copy of IBM's card-programmed calculator, at a branch of the V. A. Stekhlov Mathematical Institute in Leningrad; and the Kiev computer under construction at the Computing Center of the Ukrainian Academy of Sciences.

Computers exist in much smaller quantity in the Soviet Union than in the U.S. Furthermore, the reliability of their machines leaves much to be desired. For instance, the Strela computer at the Computing Center of the Academy of Sciences has a 10-min mean free time between errors while comparable U.S. machines normally operate for at least 8 hours without error. The reason for this probably lies in loose production controls; not so much in the building of the computer as in production of the computer's electronic components. However, as Soviet electronic technology improves, their computer technology should move rapidly ahead, since mathematical thinking about computers and computer programming is being carried on at a very high level in the Soviet Union.

Summary of characteristics

BESM I:

Binary floating point, 3-address, parallel. 32-bit mantissa, 5-bit exponent.

Has 1,000-word magnetic core memory in place of original Williams tube storage.

Average speed — 8,000-10,000 operations per sec.

31 instructions in its command list.

One magnetic drum, 5,000 word capacity, 750 rpm.

Four magnetic tape units, each of 30,000 word capacity.

Reading and writing speed is 400 words per sec. Machine can compute while searching tape.

Input—20-word-per-sec punched paper tape reader.

Output—(a) recorded on magnetic tape and then printed on photographic film off-line.

or (b) printed directly by a small mechanical printer at 20 lines per sec, each line having 10 numerical characters.

Construction is in form of plug-in packages, a typical one having a two-tube flip-flop and two cathode followers. All are hand built, and no attempt has been made at miniaturization. Vacuum tube logic is used, the only semiconductor diodes being in a group of plug-in matrices used for various subroutines (e.g., sin x and cos x).

BESM II:

This is essentially a modernized version of BESM I. The organization and logical structure are similar to those of BESM I, and the machine will accept programs written for BESM I. It is to have 2,000 words of magnetic core memory. (Like the BESM I memory, this will be "word-organized". Selection is done in a separate set of magnetic switches, and the memory cores perform only a memory function. Two cores per bit are used to equalize the load on the drivers.) Plug-in packages are smaller and neater than in BESM I. Semiconductor diodes are used in place of the vacuum diodes. This machine is to be placed in serial production.

SETUN:

Ternary, fixed-point, 3-address serial.

Word length is 18 base—3 digits, two of them to left of radix point.

Has a normalization operation for use in programmed floating point.

Uses an iterative subroutine in place of built-in division . . . 27 instructions in command list. Has 162 half-words of core storage and 2,000 words of drum storage . . . 14 millisec maximum access time to drum. Circuitry consists of magnetic amplifiers using ferrite cores. Operates synchronously at 200 kc. Only about 70 tubes in entire machine. Drum reading amplifiers use transistors.

Input-output is punched tape at 400 characters per sec. Transfers are in blocks of 54 characters with space of 15-20 characters between blocks. Addition time 180 microsec; multiplication time 360 microsec. (Both exclude memory access time.)

Magnetic tapes to be added later.

(This is an experimental machine under construction at Moscow University. Its name is that of a creek which runs past the university.)

KIEV:

Binary, fixed-point, 3-address, parallel.

41-bit word length.

2,000-word magnetic core memory.

Average speed—6,000 operations per sec.

Does not have built-in division operation.

Does have built-in binary-decimal and decimal-binary conversion.

Has three magnetic drums, each of 4,000-word capacity; 1,500 rpm; RZ recording; drum addressable by blocks or by individual 1,000 words; 84 tracks per drum.

Input from punched film (not paper tape) at 40 words per sec. Punched card input under consideration.

Circuitry asynchronous, using static trig-

ger, made with vacuum tubes. Signals are stored as levels in these flip-flops but are transmitted as pulses by diode-transformer gates.

Pulses are 0.3 microsec. Flip-flop rise time is 0.7 microsec. OR is performed by multi-winding ferrite cores with a common output winding, as well as by diode logic at a grid.

Number convention: numbers are stored as a sign and a magnitude, but arithmetic is done with diminished radix complements.

Tube count—about 2,000.

STRELA (Arrow):

3-address, 43-bit word.

Floating point, either binary or decimal.

Binary mode—33-bit mantissa and 6-bit exponent.

Decimal mode—9-decimal mantissa and 5-bit exponent.

Storage—1,023 words of electrostatic tube.

Four magnetic tapes, each about 4 in. wide and having 43 tracks in parallel.

Input-output—punched cards.

Speed—2-3,000 operations/sec.

A factory-built machine, total production being perhaps 15.

URAL:

A smaller machine, using a magnetic drum as its principal memory. It has a word length of 36 bits, is single address, and executes about 100 operations per sec. Drum capacity is 1,023 36-bit words or 2,047 instructions. Command list has 29 instructions.

Input and output are by means of punched photographic film, each strip having a capacity of 10,000 words. The machine has 870 tubes. This is also a production type machine, the total number produced being possibly 100.

7 Slices From the Economic Cake . . .

S. W. HERWALD, Air Arm Div., Westinghouse Electric Corp.

S. W. Herwald was a top-notch servo specialist before he was promoted to managerial level by Westinghouse and became sharply interested in the economics of control engineering. After earning a BSME at Case Institute of Technology in 1939, he joined Westinghouse where he performed a number of assignments in aircraft fire control development. At night he took advanced courses, earning a MSME (thesis on gyroscopes) and a PhD (thesis: servomechanisms). He is now manager, Westinghouse Air-Arm Div.

U.S.S.R. industry, as I saw it, can be likened to an extremely large corporation in which the Soviet Union owns all the stock and manages the enterprise. The key group in this "corporation" is the Central Planning Committee, which approves production quantities and prices for each and every article produced in every plant. Yearly plans are generated by individual plant directors and the trading organizations they supply, and negotiated with the Planning Committee for the subsequent year. The yearly plan is subdivided into monthly targets and relative monthly performance thereby judged. Plans are roughed out for the subsequent five years, except in the metallurgical industries, which are on a seven-year cycle.

A trading organization assumes all planning and costs of marketing and distribution for a group of plants making similar products. They take plant products at the planned prices and set market prices and distribution volumes. We got very little information on these organizations, but it appears that selling prices are not necessarily related to production costs. Instead they are set to arbitrarily balance purchasing power against production. For example, a man's wristwatch produced for 28 rubles sells in downtown Moscow for 380 rubles.

. . . For profits and taxes

The word "profit" is used by all Soviet plant managers to describe the difference between the price set in the yearly approved plan for a plant's production, and the actual cost to produce them (including design, manufacturing, and materials). Running between 6 and 10 percent, profit includes no sales or application engineering charges. A fraction of this profit, ranging from $\frac{1}{3}$ to $\frac{2}{3}$ and averaging 40 percent, is used by the individual plant to pay for special awards (for suggestions, technical designs, etc.), workers' housing, rest homes, sports programs, clinics, vacations, and technical schools. The remainder of the profit returns to the central government and may be viewed as a dividend or as a tax, depending on how far one wants to carry the "corporation" concept. When we asked in Leningrad about plants that either didn't meet their plan or made no profit, we were told that only two or three plants in that economic region had that problem. We were also told that special methods institutes and planning groups go in to improve operations in a plant that consistently runs behind. Rather than remove its director, techniques are transferred from successful plants and the successful plant paid a bonus. As if to corroborate this, all the plant directors we met had long service in their positions.

. . . For management and workers

Most factory workers are on piecework and their norms are tied to the plan for the product they are producing. The more they produce, the higher their take-home pay; 110 to 140 percent appears to be the spread for piece-worker take-home. The lowest pay is 350-450 rubles per month and the highest about 2,500, with an average between 800 and 1,000. Each job is associated with a classification that attaches higher salaries to higher skills.

Salaries without bonuses vary from 4,000 to 7,000 rubles per month for plant directors, and from 3,000 to 6,000 rubles per month for chief engineers. With bonuses, directors earn 7,000 to 10,000 rubles per month.

Management has a bonus geared to the approved plan. For each month during which the plan is met in all details the director and his key people receive a bonus ranging from 20 percent to 40 percent, based on a percent

schedule that is part of their approved plan. Differences in bonus schedules presumably are set as an added incentive for plans difficult to meet, or to encourage production of critical items. Remaining salaried employees receive bonus percentages that are from one-third to two-thirds of management's. For exceeding the plan, the bonus is increased, again on a preset schedule, with variations between ½ to 4 percent for each percent that production exceeds the plan. The ceiling bonus is 100 percent of base pay.

In addition, each economic region, such as those centered in Leningrad, Tula, and Moscow, pays a special quarterly award for excellence in production, labor relations, safety, improvement of capital equipment, etc. Known as a "Socialist Emulation Award," it is paid to the winner of a competition among those plants in an economic region that make similar products. The "Vibrator" (meter) and "Kinap" (cinema equipment) plants are members of a group of 26 *pribori* (instrument) plants that ran in the competition conducted by the Leningrad Economic Region during the second quarter of 1958. First place earned one month's additional pay for each employee of the winning plant; second place, a half-month's pay; and third place, a quarter-month's pay. Judges selected from trade union officials, plant administrators, and economic region officials chose the winner.

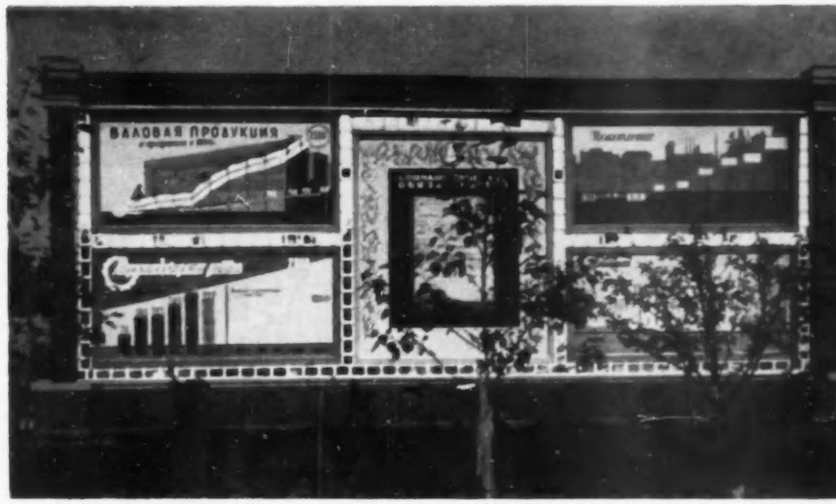


FIG. 19. Multicolored billboard at the Leningrad Electro-Mechanical Plant (manufacturer of watt-hour meters) shows, reading clockwise from the upper left: the plant's percentage growth in gross production since 1950; thousands of rubles invested annually in plant; growth in construction of residences for plant workers; and rationalization of work.

Individual plants have trade unions that represent the worker on salaries and working conditions. Union officials are selected by the workers and are involved with management in approving such benefits as a reduction in working hours with no reduction in pay, as at the ZIL (automotive) works. Although we tried very hard to determine what happens to a poorly performing worker, the answer always seemed to be that "there was no unemployment" so they couldn't fire anyone. They did, however, indicate that in extreme cases the union would agree to down-grading as a penalty for poor performance. It was also stated that although the workers had no right to strike, any problem not resolved by local plant management with trade union officials could be carried to a higher group for arbitration. The exact mechanics were not defined.

. . . For funding

Chief Engineer K. Stroganov of the ZIL works discussed financing for cost reduction expenditures and material inventory. The government bank loans interest-free money for small efficiency-improving plant expenses and grants capital funds once a plant expansion program has been approved by the Central Planning Committee. Loans for inventory bear a 3-percent interest charge. Payrolls and receipts from the trading organization feed through the bank just as ours do.

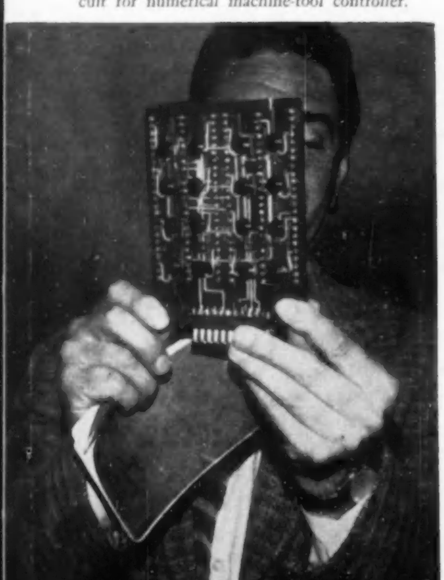
Soviet industry has adopted—and accentuated—all of the incentives, fringe benefits, and planning associated with American free enterprise. The old Socialist saw of equal pay for all is totally ignored; their current system places tremendous financial incentive upon quality and quantity of performance. Industry is run by skilled professional men and women. Up to now they have performed spectacularly, aided by fundamental reasons that are about to vanish. One is that they were so far behind that they could progress rapidly just by copying. This they have done. Another is that the demand for all manufactured products has been constant for so long that the only problem was to produce.

With the shortage of manufactured goods that exists in the Soviet Union today, they have been able to save considerable design and tooling effort by restricting the sizes and varieties of products they make. The consumer takes the standard design or none. Industry has only certain standard motors, turbines, switchgears, etc., to select from. Most nonstandard modifications, which they tend to avoid, are made in the user plants.

As production increases, the internal U.S.S.R. market will saturate. Demands will become more subtle and selective. It remains to be seen whether the complex control mechanism of the Central Planning Committee can cope with this problem—one that American industry faces every day.

Official exchange rate is 4 rubles per dollar; tourist rate is 10 rubles per dollar; but the actual purchasing power of the ruble is quite arbitrary. Ed.

FIG. 18. U. S. systems manufacturer Herwald displays Soviet-made transistorized pulse circuit for numerical machine-tool controller.



FORWARD, BUT NOT ALONE

Soviet control engineers have pulled abreast of their Western contemporaries in technical knowledge. They should have, for it is on the West's technical know-how that they have ridden forward. (Figure 20 shows copies of untranslated Western journals offset-printed by the GSTC for rapid distribution of Western engineering techniques to Soviet engineers.) They have nevertheless drawn slightly ahead in abstract theories of nonlinear control, random processes, and self-adaptive control.

They have demonstrated great ability at mass producing standard products, but they lag in developing and producing sophisticated products such as analysis instruments, complex data acquisition systems, and static switching systems. Their scores of standard products are applied with ability and some originality. For instance, control men at the ZIL works have developed a system that, from the driver's cab, regulates the pressure of each tire on the new six-wheel ZIL 157 military and agricultural truck. Other Soviet engineers have perfected miniature magnetic cores with holes cast in them for nondestructive interrogation. But lacking in the variety and wealth of control products with which we are blessed, they have not shaped so broad a link between theory and practice as we have.

Although pleased with their progress in perfecting and applying standard products, they are, even so, either uncertain about their next steps or about their ability to take them alone. They have built prototypes of extremum controllers (and applied them in petroleum refineries, we were told), yet they showed keen interest in purchasing Quarie controllers at the ISA Exhibit in mid-September. U. S. digital systems for industrial control are on their shopping lists. So are electronic process control systems, specifically the new designs shown by Foxboro and Leeds & Northrup.

Britain has already been approached to give them a hand up the next few steps. A year ago Machineryimport, the authority that handles control and machinery imports to U.S.S.R., requested quotes from British control manufacturers for completely automatic oil refineries, aluminum plants, fertilizer plants, and copper, tin, and zinc ore crushing plants. The British firms found so many gaps in the control schemes proposed by the Soviets that they suggested two phases for the quotations: first feasibility studies (for which they were paid) and then, actual quotes on complete systems. The Soviets gained know-how, and the British may have made their expenses, but no one knows what will happen next in this exchange, for the Soviets are stalling on the second phase. One British manufacturer who journeyed to Moscow to sell his quotation was stopped cold by a Russian request for advice on how to sell Soviet control products in Britain.

A hand-up for the Soviets may mean a hand-down from them, for while Soviet control engineers seek to purchase the latest in control systems, the Soviet control manufacturing industry is trying to open international markets for its products. Its exhibits at the Vienna Fair during the week of Sept. 7 show that it is ready to market not only system components but also systems such as those designed for them by the British. One system shown there completely controls the collecting, weighing, and unloading of charges for blast furnace scale cars. Each scale car carries its own control system. Another system synchronizes rolls and controls the speed of hot rolling mills. It is powered by mercury arc rectifiers, not by rotary converters.

Now they want to buy from the U.S.—equipment and knowledge they have not yet developed on their own.

FIG. 20. Felker of Bell Tel Labs examines a complete offset copy of The Bell System Technical Journal found on a rack containing offset copies of U. S., U. K., and German journals. Place: "Kinap" plant, Leningrad.

Picture Credits

With his Minox camera and strobe-flash, P. S. Sprague, president of The Hays Corp., Michigan City, Ind., took the photographs identified with figures numbered 5, 10 through 13, 15, 16, 18, and 20. G. C. Newton, Electrical Engineering Dept., MIT, snapped number 9 at the Industrial Exhibit.

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A CONTROL ENGINEERING SPECIAL REPORT

Electronic Process Control Systems

Recognizing the full status of electronic control, CONTROL ENGINEERING presents a 16-page report on this subject. Full stature as a control medium is evidenced by the recent marketing by four more companies—in addition to pioneers Swartwout and Manning, Maxwell & Moore—of extensive electronic control systems. These other companies are Taylor, Foxboro, Minneapolis-Honeywell, and Leeds & Northrup.

The report starts with three questions asked of a user, a contractor, and the makers of the new electronic systems. Their candid answers should interest you. The basics of electronic control systems follow next. This is an interpretive report, not a substitute for product bulletins and detailed training available from manufacturers. Since the electronic system is not complete without an electrically signalled actuator, the actuator is covered also, along with the highlights of the six control systems.

HARRY R. KARP, Control Engineering

WHY DID YOU USE ELECTRONIC CONTROLS? "For the past few years we tried several small installations of electronic control systems," replies an instrument engineer at a midwest oil company, "and we learned a few things that made us decide to use electronics again in our new refinery. Of course, we have a few gripes, too. As for benefits of electronic control systems, one is that they are inherently more sensitive and they have been installed where sensitivity can do the most good—better tuning of temperature loops. Electronics is more compatible with data logging and computing control, which we plan to have later. We left space for them in our control room.

"Our refinery must operate continuously, and we find it harder and harder to keep instrument air systems completely reliable for this requirement. Even in our moderate climate, six air freezeups occurred last year during five winter months. And because of equipment troubles in our air drying and regenerating system we had to change over from automatic operation to manual to assure a good supply of air. With electronics we should have less of an air problem but we do need a standby electrical system in case of power failure. For this, we have an emergency generator that keeps the electronic instruments operating.

"Our experience shows that electronics performs for longer periods of time with less maintenance once the instruments have been installed and checked out, and that for our applications electronics is comparable in performance to pneumatics. Electronics cost the same as pneumatics, because contractors gave us the option of electronics or pneumatics, take your choice. This option occurred on three different jobs, and on one job quite a few bidders—all, in fact—made the same offer.

"Yes, we had troubles with our electronics installation. There was more difficulty installing 50 electronic loops than there was installing many times that number of pneumatic loops. We encountered poor soldering connections and shorts in the controllers and nonrepeatable transmitters. Instruction manuals are not suitably prepared for checking out the instruments and there is no orderly trouble-shooting approach. Once we got by these troubles, the instruments worked fine."

WHY ARE YOU NOW MARKETING ELECTRONIC CONTROL SYSTEMS? "User demand," answers one of the four companies who recently announced new systems. "There are many applications calling for just a few control loops," says another maker. "Don't forget, there are many industries—ceramics, nuclear power, pipelines, food, and utilities—that need control systems but not extensive ones like those used in petroleum refineries and large chemical plants. For these 'little guys' electronics means a low-cost control system that can be easily connected to the plant electric power service without making an investment in an air system they would otherwise need for pneumatics."

"What many people may not appreciate," states a third maker—who, like the other three that are beginning to market electronics control systems, also builds pneumatic systems—"is that electronics is not new to the process industries. For years, such electronic instruments as potentiometer-transmitters, servo multipoint recorders, and ultraviolet analyzers, have been used successfully in many plants. All we're doing now, with our new line of small, panel- and console-mounted electronic control instruments, is to perform certain functions electrically instead of mechanically or pneumatically."

WHY DO YOU RECOMMEND ELECTRONIC CONTROL SYSTEMS? "We evaluate jobs on an individual basis to see what instruments are needed, what specifications are set for various areas of installation, and what the overall costs will be." This reply comes from the chief instrument engineer of a contractor company. "We won't always recommend electronics, obviously, but we will when in our opinion they can do the job better. Of course, the client may have some fixed opinion on what he wants. Sometimes clients want electronics, even if it looks like it may cost a little more, just to get some actual experience and data on which to make future decisions.

"To counter the statement made by the refinery engineer, or more specifically, to clarify the point he raised that electronics cost him the same as pneumatics, I want to point out that the contractor charged the client the same price, but this does not mean that the cost to the contractor was the same. For a large contract, the instrument cost is a small percentage of the total cost, and any difference between electronics and pneumatics is even a smaller percentage of the total cost. Contractors apparently were willing to absorb the small difference, particularly lately, when business was slow. However, in my opinion, quoting the same price for electronic and pneumatic control systems is not a responsible approach. There is enough information available on instrument and installation costs to make an accurate estimate for both electronic and pneumatic control systems."

THE BASICS OF ELECTRONIC CONTROL SYSTEMS

Broadly speaking, the "packages" available for electronic control are similar in function to the "packages" available for pneumatic control. There is one essential difference, however. The industry-accepted signal for pneumatics is 3-to-15 psi. Such pneumatic components as transmitters, controllers, and recorders produced by different manufacturers (but each having certain features desired by the user) are readily compatible in a control loop. In electronics, on the other hand, the different signal types and levels adopted by each manufacturer (see table) preclude direct compatibility between one manufacturer's transmitter and another manufacturer's controllers. No doubt the future will see users and manufacturers develop modularized "matching circuits" permitting interchangeability.

Some compatibility presently exists between control and actuation. The table shows that all electronic controllers have a dc current output and a 5-to-1 ratio between maximum and minimum signal. Any electrically signaled valve actuator can be modified (possibly including amplification) to accept any controller signal. Thus, the task of making an electric valve

CHARACTERISTICS OF ELECTRONIC PROCESS CONTROL SYSTEMS

	MINNEAPOLIS-HONEYWELL	SWARTWOUT	TAYLOR	FOXBORO	MANNING, MAXWELL & MOORE	LEEDS & NORTHRUP
CONTROLLER						
Input*	4-20 ma dc	0-0.5 vac	0-200 mv ac, or 1-5 ma dc	10-50 ma dc, or 0.4-2.0 ma dc	1-5 ma dc	1-5 ma dc
Output	4-20 ma dc	1-5 ma dc	1-5 ma dc	10-50 ma dc	1-5 ma dc	1-5 ma dc
External load	0-1,500 ohms	12,000 ohms	10,000 ohms	600 ohms	3,000 ohms	500-2,500 ohms
Actions:						
1) Proportional band	0-300 percent	2.6-200 percent	0.4-200 percent	50-400 percent	3-200 percent	0-300 percent
Reset	0.1-100 rep/min	0.1-380 rep/min	0.05-32 rep/min	1-30 sec	0.5-0.005 min/rep	0-100 rep/min
Rate	0-8 min	0.003-10 min	0.0016-24 min	—	0.5-0.005 min	0-8 min
Amplification	Vacuum tube	Vacuum tube	Vacuum tube	Magnetic amplifier	Transistor & tube	Transistor & tube
2) Proportional band		2.6-200 percent	4-2,000 percent	2-500 percent	3-200 percent	
Reset	(Also without	0.03-120 rep/min	0.5-320 rep/min	0.01-25 min	5.0-0.05 min/rep	
Rate	rate)	0.003-10 min	0.0016-24 min	0.01-25 min	5.0-0.05 min	
Amplification	Vacuum tube	Vacuum tube	Vacuum tube	Transistor	Transistor & tube	
RECORDER						
Input	4-20 ma dc	0-0.5 vac	0-200 mv ac, or 1-5 ma dc	10-50 ma dc	1-5 ma dc	1-5 ma dc
Pens	1 or 2	1 or 2	1	1 or 2	1 or 2	1 or 2
Chart width	4 in.	3 in.	4 in.	4 in.	3 in.	4 in.
Amplification	Transistor	Vacuum tube	Transistor	Not needed	Vacuum tube	Vacuum tube
TRANSMITTER (PRESSURE)						
Output	4-20 ma dc	0-0.5 vac	0-200 mv ac	0.4-2.0 ma dc	1-5 ma dc	1-5 ma dc
External load	0-800 ohms	Extremely high	Extremely high	10,000 ohms	3,000 ohms	500-2,500 ohms
Wires needed, total	2	4	4	4 (2 for d/p cell)	4	4
1) Signal wires	2	2	2	2	2	2
2) Exc. or field power wires	Not needed	2	2	2	2	2
Must 2) come from receiver?	Does not apply	Yes	Yes	No	No	No
Amplification	Transistor	Not needed	Not needed	Magnetic amplifier, for 10-50 ma output	Vacuum tube	Transistor
TRANSMITTERS AVAILABLE						
Process pressure	Yes	Yes	Yes	Yes	Yes	Yes
Differential pressure	Yes	Yes	Yes	Yes	Yes	Yes
Emf (temperature)	Yes	Yes	Yes	Yes	Yes	Yes
Ac-ac adapter	—	Yes	—	Not needed	—	Not needed
Dc-ac converter	—	Yes	Yes	Not needed	—	Not needed
Resistance	Yes	Yes	Yes	Yes	Yes	Yes
Liquid level	Yes	Yes	Yes	Yes	Yes	Yes
ACTUATION AVAILABLE						
Electropneumatic transducer	Yes	Yes	Yes	Yes	Yes	Yes
Electropneumatic positioner	Available later	—	Yes	—	Yes	—
Electrohydraulic positioner	Available later	—	—	Yes	Yes	—
Electrovapor positioner	—	Yes	—	—	—	—

*To error detector, if applicable.

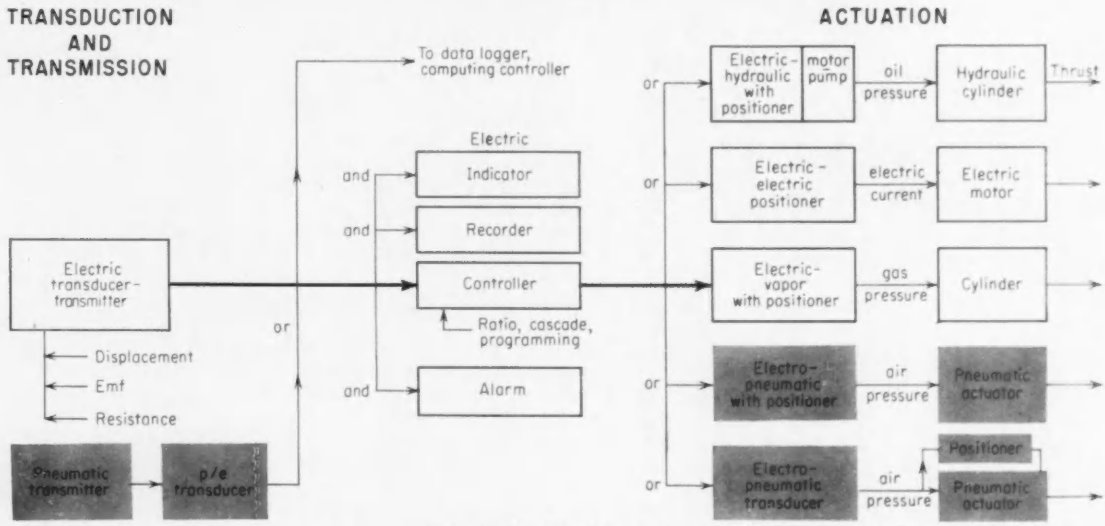


FIG. 1. Some possible arrangements of electronic control systems, including pneumatic components (shown shaded) for use in hybrid electro-pneumatic systems.

actuator compatible with all controllers falls on actuator and valve-positioner makers. Makers' bulletins state their readiness to meet this problem.

Within any compatible electronic control system, numerous component arrangements meet almost any operating requirement. Figure 1 shows some possibilities. One can have a process-variable measurement combined with indicating only, or indicating-controlling, or indicating-recording-controlling, or cascading, or recording only, and so forth. Add to this a choice between four ways of converting the controller's electrical output into a valve thrust and three basic transmitter types for measuring common controlled variables—and the versatility of electronic controls expands even further.

Common functions in electronic control

Each electronic control system, regardless of inherent differences, performs these common functions, Figure 2:

1. Measures the process variable and transduces it to an electrical signal for transmission.
2. Compares the transmitted electrical signal with the desired value of the process variable (that is, the set-point established as an electrical signal) to develop an error signal.
3. Characterizes the error signal, through proportional, reset, and rate actions in a controller, into a controller output appropriate to process dynamics.
4. Converts the controller's electrical output signal into a corresponding stem position of an electrically signaled (valve) actuator. The actuator operates a valve, modifying the manipulated variable to restore the controlled variable to its desired value.

Transmitters

As shown in Figure 1, three basic transmitter types measure and convert almost any process variable into an electrical signal for transmission.

The displacement-type transmitter: senses a controlled variable as a motion. For example, process pressure is measured by movement of a Bourdon tube, as in Taylor's transmitter, Figure 3. This movement then is converted to a corresponding electrical output through a displacement-to-electric converter. Swartwout, Foxboro, and Taylor pressure transmitters displace the core or ring of a differential transformer, thus changing the transformer's ac output. (Foxboro rectifies to dc current before transmitting.) Minneapolis-Honeywell and Manning convert displacement to torque and use the dc current needed to create a beam-balancing torque as the proportional signal. Displacement-type transmitters measure such variables as process pressure, differential pressure, level, and displacement.

The emf-type transmitter: senses electromotive force, for instance the dc millivolts from a thermocouple, and converts this low-level signal to a higher-level dc cur-

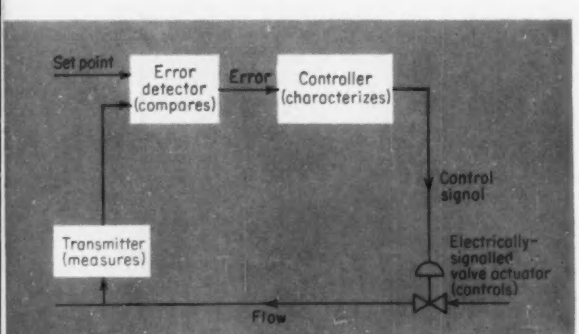
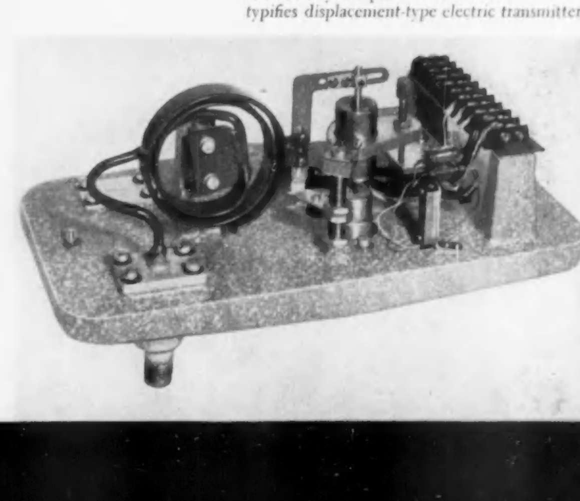


FIG. 2. Common functions in electronic control.

FIG. 3. Taylor's pressure transmitter typifies displacement-type electric transmitter.



rent or ac voltage, depending on that needed for system compatibility. Emf-type transmitters measure such variables as temperature (thermocouple), speed (tachometer), and pH (pH meter).

The resistance-type transmitter: senses the controlled variable as a change in resistance, uses this change to (for example) measure temperature with a resistance temperature detector (RTD). With a Wheatstone bridge, as in Foxboro's transmitter, Figure 4, the bridge's unbalance (output) voltage is then a function of temperature. Additional circuitry provides the proper voltage or current output for system compatibility. Typical resistance-type transmitters measure temperature (RTD), stress and strain (strain gage), weight, (strain gage load cell), and position or angle (resistance potentiometer).

Error-sensing circuit

The error-sensing circuit compares the controlled process variable signal with the (adjustable) set-point signal, the desired value of the controlled variable. Following a disturbance, the circuit delivers an error or deviation signal proportional to the magnitude of the difference between the signals; and with a polarity (or phase) that indicates whether the measured signal is larger or smaller than the set-point signal. The error cannot be reduced exactly to zero, even after the disturbance is corrected. Some small input must be applied to the controller for it to develop that actuator current needed to maintain the valve (adjusting the manipulated variable) as a stem position giving the desired value of the controlled variable. The error remaining varies with load conditions at the valve.

In the six electronic control systems, error-sensing is accomplished by one of two basic methods: voltage comparison or force or torque comparison.

Voltage comparison: measured and set-point signals are both voltages. For ac voltage systems, Figure 5A, the measured signal comes from a transmitter's differential transformer. The set-point signal comes from another differential transformer whose iron core is fixed in a position giving an output voltage corresponding to the desired value of the process variable. The two signals are compared in an ac amplifier, the output of which then goes to a phase-sensitive converter providing a polarized dc signal proportional to error magnitude and direction.

For dc current systems, Figure 5B, the measured current signal passes through a fixed value of resistance, establishing a dc voltage across the resistance proportional to the process variable. The set-point is readily set up as a voltage from a low-power voltage regulator. Then the two voltages are compared, again giving a polarized dc voltage proportional to error magnitude and direction. The error voltage goes to controller input for control signal characterization.

Torque or force comparison: here three forces create torques on a pivoted beam. They are the set-point force, the force due to the magnitude of the transmitter current, and a beam-balancing force. Torque-comparison error-sensing automatically generates enough current (or force) in electromagnetic coils to balance the beam so that at balance the set-point torque minus the measured-variable input torque equals the balancing torque (or, at balance the net torque equals zero).

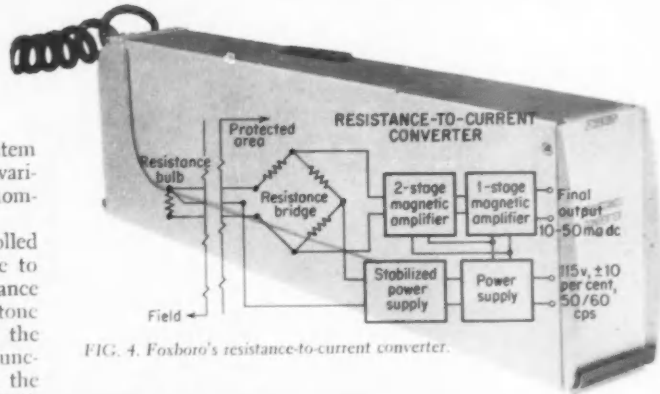
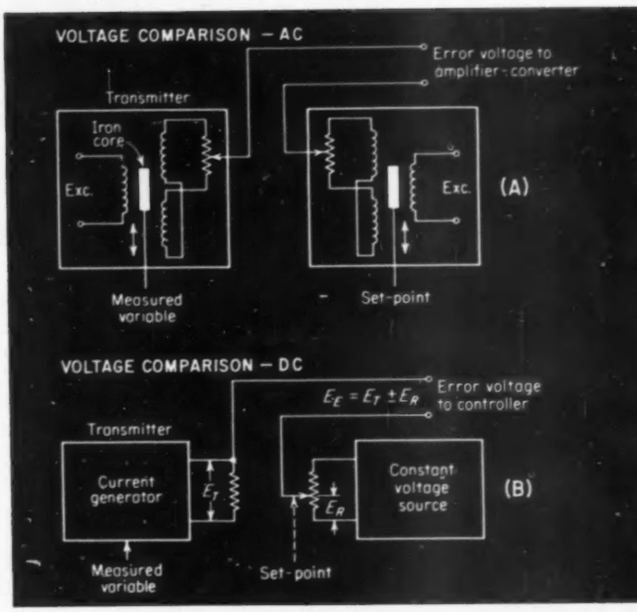


FIG. 4. Foxboro's resistance-to-current converter.

FIG. 5. Typical circuits for ac and dc voltage error senser



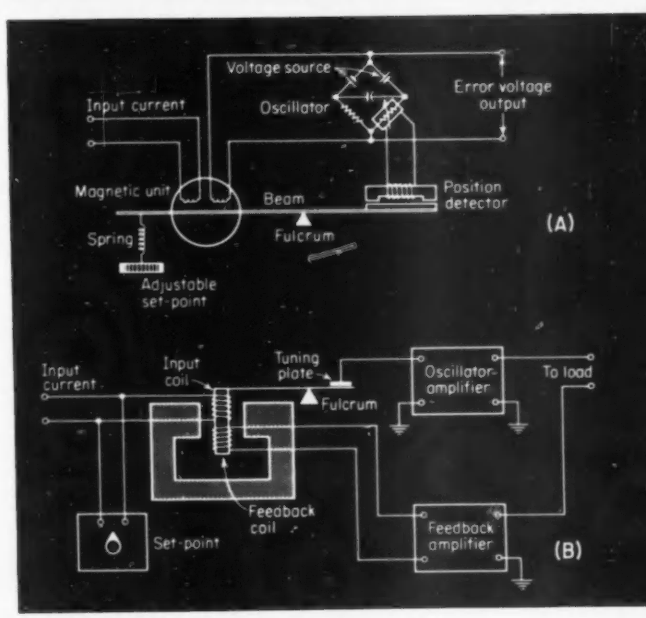


FIG. 6. Beam-balancing torque develops error signal.

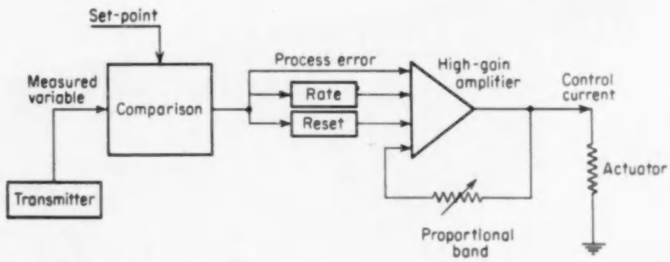


FIG. 7. Generalized concept of a three-mode controller.

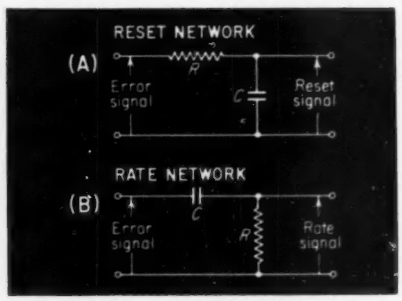


FIG. 8. These circuits are basic to reset and rate actions. Often amplification must be included with these circuits.

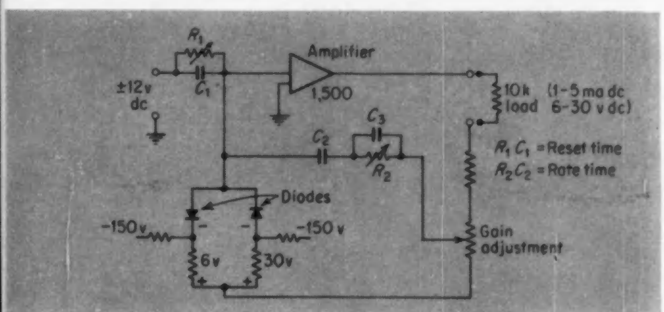


FIG. 9. Basic circuit of Taylor's controller.

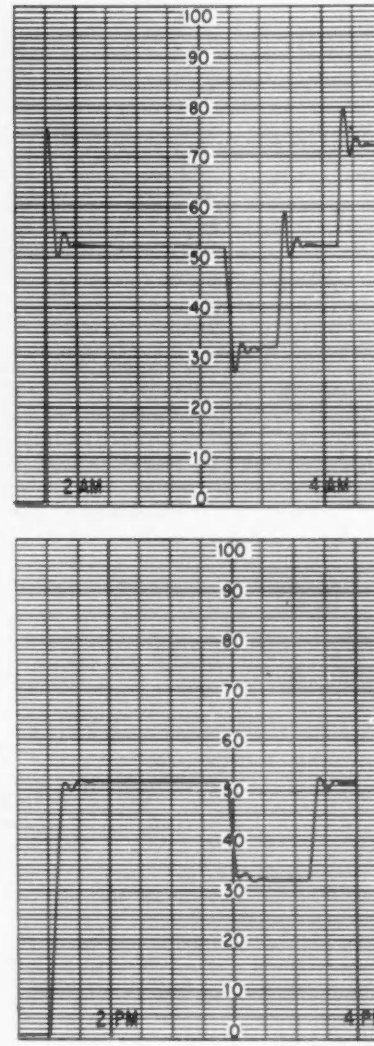


FIG. 10. Response, top, to disturbance when using standard controller; response, bottom, using anti-reset windup circuit shows faster return to set-point and reduction of overshoot.

The dc voltage equivalent of the balancing force is the error signal that goes to the controller.

In the Honeywell system, Figure 6A, the set-point force is a calibrated spring action on the beam. Two separate coils, one for signal current and one for balancing current, also develop forces. Beam balance is noted by a position-detector, which adjusts an oscillator-amplifier to give a voltage output proportional to magnitude and direction of process deviation. Note that immediate balance occurs through forces created in the error-sensing portion of the control system.

In the Manning system, Figure 6B, the set-point is an adjustable current; the measured signal is also a current. Both currents come from high-impedance sources that are differentially connected (compared) across a low-impedance coil acting on the beam so that the coil creates a torque or beam deflection proportional to process deviation. The small deflection varies oscillator-amplifier output current which—in addition to signaling the valve actuator—is fed back to another winding on the coil and balances the beam. In this case, the oscillator-amplifier is actually part of the controller and the balancing force responds also to the dynamic characteristics included in the controller's electronic feedback amplifier.

Controller

The electronic controller provides adjustable proportional, reset, and rate actions (or modes) that characterize the error voltage (process deviation) according to process dynamics requirements. That is, the particular settings of the individual actions depends on process characteristics. Ideally, the circuit for each action is independent of the others, so that an adjustment of one action has no effect on the settings of the others. Figure 7 shows one generalized concept of a three-mode controller.

Proportional action: delivers a controller output current to the valve actuator directly proportional to the magnitude of the signal from the error-sensing circuit. Proportional action is a static characteristic; once set,

it remains constant. The constant of proportionality is known variously as proportional band, throttling band, sensitivity, and gain. It occurs through simple electronic amplification of the error signal. Usually the desired proportional band is obtained by changing the amplifier's negative feedback.

The proportional band (or its reciprocal, gain) can be larger or smaller than unity, and is stated in nondimensional terms. Proportional band expresses as a percentage of total controller input range the error moving the valve actuator through its full range.

Reset action: exaggerates proportional error by producing a signal that is the integral or sum of the error signal over the time it exists. The longer an error persists, the larger will be the output signal of the resistance-capacitance reset network, Figure 8A. The controller adds the proportional-error and reset signals, and thus its output current is larger than it would be for proportional error alone. Processes controlled by proportional action only will have a sustained steady-state difference between set-point and controlled variable, called offset. Reducing the proportional band (increasing gain) can reduce offset, but this approach cannot be carried too far because then the system becomes unstable. Reset action can reduce offset, however, since now the small existing process error builds up over a period of time to be a large enough effective controller error to drive the controlled variable toward the set-point value. The reset signal automatically remains large enough to develop an extra valve thrust compensating for the offset.

The units of reset are repeats per minute or its reciprocal, minutes. Suppose the reset is two repeats per minute; this means (assuming the error remains constant) that in 1 min effective controller error is triple (2 plus 1) that from proportional action only. The controller output current is three times what it would have been with proportional action only, and the valve moves three times as far to minimize deviation.

Rate action: exaggerates a proportional error changing with time by producing a signal proportional to the time rate of change of the error. The faster an error changes, the larger will be the output signal of the rate network, Figure 8B. The controller algebraically adds the proportional-error and rate signals together. At the beginning of a disturbance, for instance, the controller output current is larger than it would be for proportional error alone. Thus, the valve is driven in the correcting direction at a faster rate; and about the same rate the disturbance creating the error in the first place tries to upset the process.

Figure 9, the basic circuit of Taylor's controller, shows how that company obtains three-mode control. The circuit is presented here more to typify what can be accomplished with electronic control systems in the way of special functions than to dwell on circuit design for its own sake. This controller contains diode-limiting circuits that speed up corrective action after a wide deviation such as occurs on process startup or temporary loss of process energy. Normally, on a wide deviation the valve corrects by going full-open (or full-closed) and reset action delays closing (even though the disturbance has disappeared) until the measured variable returns to within the proportional band.

To reduce this delay, the diodes essentially by-pass reset signals less than 6 volts and greater than 30 volts so that reset action now comes in (after a wide deviation) at time R_1C_1 before the measured variable would otherwise reach the set-point if correction rate continued at the same trend. In other words, the diode circuits advance throttling action of the control valve by a time equal to (1/reset rate).

Control of the same process with and without the nonreset windup circuit is compared in Figure 10. The process used here is characterized by a fast ramp reaction rate followed by two equal time constants of 0.5 sec. The controller is set at a proportional gain of 16 and a reset rate of 16 repeats per min. (Note that 1 hour on the chart is actually 1 min.) The top curve shows the conventional-controller response from startup to 50 percent of controller output span, and then responses to set-point changes of minus and plus 20 percent. The lower curve shows response of the same controller with the anti-reset windup circuit operative. Note the reduction in overshoot and the shorter time for the process to settle down at the set-point.

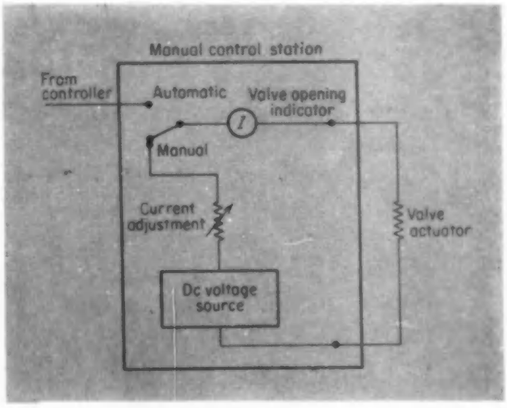
Manual control station

Occasionally, automatic control of a process is not needed (such as during startup or an emergency, when conditions may require that valve actuation be at instant command of the operator) or not available (such as when the controller is temporarily disconnected for maintenance). In these cases, the operator must have some way to adjust the final control element and keep the process on-stream. This is provided by a manual control station often separate or easily detachable from the controller, so that when the controller is removed for service the manual station remains.

The manual control station permits operator adjustment of valve opening, indication of valve opening (either on automatic control or manual control), and "bumpless" transfer of the process from *automatic* to *manual* control and vice versa. Basically, the station contains a power supply, an adjustable current control, an indicator, and necessary switching, Figure 11.

When the switch is on *manual*, the valve actuator receives its signal from the power-supply current-control arrangement, which the operator sets for the desired value of valve opening as shown on the indicator. Although the valve is disconnected, the controller remains warmed up and connected to a dummy resistance load that keeps the electronic circuitry, particularly the reset network, charged to the same state

FIG. 11. Basic details of manual control station.



it would have had during automatic operation. Without this reset network charge, a spurious disturbance, or "bump", would occur after transfer to *automatic* while the reset circuit "winds up".

Actuators

So far, the final control element of the loop has been viewed as a valve positioned by an electrically signaled actuator. This is natural, for many control loops modulate a flowing material and different types of valve actuators are available to meet process needs. However, the electrical nature of the control signal—and all the versatility this entails—make electronic control systems adaptable with simplicity and directness to other final control elements, such as saturable reactors for controlling electrically heated furnaces and thyratron amplifiers for controlling electric-motor shaft position and speed on rolling or webbing operations. The direct control of electrically-powered final control elements from low-power electric signals has the advantage of carrying out the necessary power amplification in the same energy form, namely electricity, and without concern for mechanical considerations. What can be accomplished depends on process and plant requirements and the ingenuity of the system designer.

For valve operation, to which the lion's share of electronic control systems have been so far applied, makers offer a varied line of electrically signaled actuators. Basically, such actuators are power amplifiers: they convert the low-power electrical control signal to a corresponding high-power stem thrust. In addition, they often include energy-conversion as well as amplification, because the control signal modulates pneumatic (air), hydraulic, and gas forces as well as electrical power. From the stem motive power used come these names assigned to electrically signaled actuators:

►electromechanical—actuators electrically amplify the signal to power an electric motor which, through a gear train, drives the actuator's stem to the desired position.

►electropneumatic—actuators transduce the electrical control signal to a proportional pneumatic signal in the 3-to-15 psi range, and this pneumatic signal actuates the stem of conventional pneumatic actuators. Transduction may include positioning, a closed-loop connection from the valve stem to the air control signal which adjusts diaphragm pressure until the stem reaches commanded position. Some devices incorporate the positioning effect in the actuator, as exemplified by the Moore Products Co. Electro Pneumatic positioner, Figure 12.

►electrohydraulic—actuators use hydraulic pressure, generated by a pump driven by an electric motor, to move the stem. The electric signal modulates one or more stages of hydraulic amplification through pilot valves. Stem-position feedback is generally included.

►electrovapor—actuators use controlled vapor pressure generated by electrical-heating vaporization of a self-contained fluid. This actuator is new; it was introduced recently (CtE, Oct., p. 117) by Swartwout.

Transmission

The simplest way to transmit electrical measurement and control signals to and from the process is over pairs of copper wires. Some transmitters require two additional leads to supply power to excite the transmitter, and (some) systems using differential transformers require that these leads come from the same source that powers the set-point signal in the controller. Thus, where separate transmitter exciting power is needed, it may be furnished from a central source located in the field or carried from the controller to the field. The terms two-wire systems and four-wire systems specify the number of wires per transmitter.

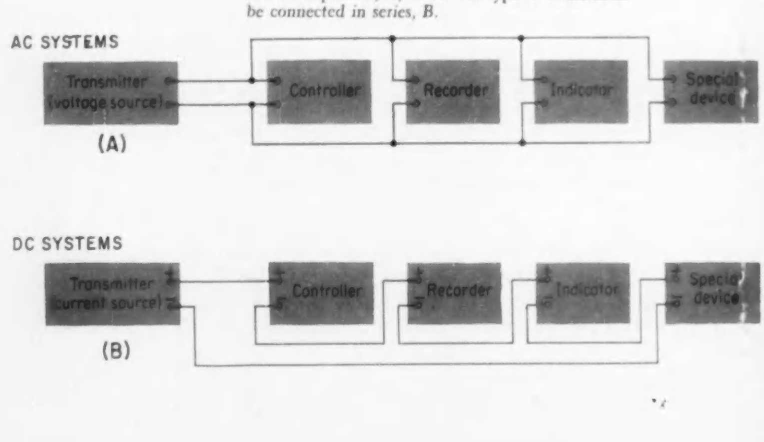
Signals from transmitters go to such receivers as indicators, recorders, controllers, and special devices. For ac voltage signals all receivers are connected in parallel across the transmitter, as shown in Figure 13A. These receivers have high impedance inputs compared with the impedance of the transmitter, so that many can be connected in parallel without error.

Because of the high impedance, the resistance of the copper leads in the transmission circuit is not too critical; but it should not be so large that voltage drop (due to small signal current flowing through the lead resistance) becomes greater than a fraction of a percent of the signal voltage range. Generally, wire size is determined more by mechanical considerations (that is, the wire must be strong enough for it to be pulled through conduit) than resistance considerations.

For dc current signals all receivers are connected in series with the transmitter, as shown in Figure 13B. Current-type transmitters have an external load resistance specified by the maker, at or below which they will operate satisfactorily. Receivers for such transmitters have specified input resistances. Because

FIG. 12. Moore E/P valve positioner typifies one way to convert electric control signal to pneumatic actuation.

FIG. 13. Ac-voltage-type receivers must be connected in parallel, A; dc-current-type receivers must be connected in series, B.



of the series connection, the load seen by the transmitter is the sum of receiver input resistances plus the resistance of the copper leads. Once the total receiver input resistance and transmitter external load resistance are known, the allowable wire resistance can be determined. The wire size to give this resistance over a known distance can be found from copper-wire gage tables; so can running distance for a given size wire at the specified resistance. In determining wire size, it must be remembered that because two wires are needed per measurement the length of the wire is twice the distance between the transmitter and receiver group.

Figure 13 shows that special receivers can be connected, along with those available from manufacturers. Such devices (for instance, converters for computing, data logging, and telemetering systems) can be connected relatively simply, a virtue of electronic systems.

Still, there are certain factors that differ somewhat for different types of transmission. In dc current transmission, the series connection requires that the circuit must be closed at all times. For instance, when a local indicator (a simple dc milliammeter) is used occasionally by the operator for checking purposes, contacts (in a telephone jack) must be shorted when the meter is not functioning. Furthermore, even a circuit open temporarily (during insertion of the meter plug into the jack, for example), may not be tolerable; a momentary open circuit would appear to the control system as a maximum disturbance. This situation can be avoided by using make-before-break contacts on connectors or by measuring the voltage drop across a fixed resistor. If the receiver resistance is large, the connector can be wired to replace the receiver with an equivalent resistance. Mounting frames of commercial electronic receivers automatically provide the appropriate connectors, dummy loads, and fixed-value checking resistors.

For ac transmission, differential transformers deliver voltage signals at a fixed phase angle. Manufacturers adjust the corresponding phase angle in their receivers to those of the transmitter, so that when using standard equipment supplied by the same maker the user need not concern himself with this consideration. However, a problem may arise when the user wants to operate a special device from his ac signal. Here consultation with the instrument supplier will give the user the required information about phasing, from which the user can develop the circuitry for the special receiver. And it may be even more practical to describe receiver specifications to the electronic control system maker and let him supply the needed equipment.

Controller output current goes to the input of an electrically signaled valve actuator or other final control element. The control signal is always dc current, and the wiring considerations between the controller and actuator are somewhat similar to those stated above for dc current transmission signals. The controller has a maximum or constant permissible load resistance, the major part of which is the input resistance of the actuator and the smaller the resistance of wire connecting the controller and actuator.

Telemetering

Transmission and control signals can also be carried over long distances by leased wire or radio telemetering. One approach is to transduce the measured signal into a proportional frequency, transmit the frequency signal, and then use another transducer to convert the frequency back to the original current suitable for feeding into the controller.

Transmission of current, voltage, and frequency are continuous analog representations of the measured and controlled quantities. But there are other ways to telemeter information that often prove equally or more advantageous. These include using the same transmission link for many signals (time-sharing) and transmitting signals in such discontinuous forms as tone bursts and pulses lasting a time proportional to the magnitude of the original signal at the instant it was sampled.

As an example of what is available in telemetering equipment, consider the system developed by ASCOP (Applied Science Corp. of Princeton) for use with electronic control systems. The basic system (usually part of a larger supervisory control system) is shown in Figure 14. (Note that here the term transmitter applies to the telemetering system, while the term transducer applies to process-mounted transmitter.) The input to the telemetering transmitter requires a 1-to-5-volt dc signal, the same range ratio produced by all dc-current type (process) transmitters. Current is converted to voltage by passing the current through a constant resistance of appropriate value. For other types of measurements, the voltage can be obtained across retransmitting resistance slidewires and by amplifying thermocouple outputs.

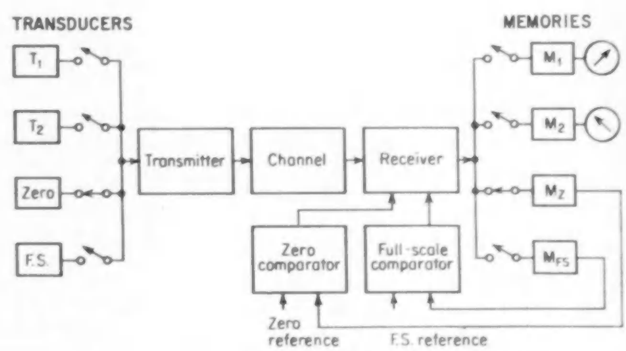


FIG. 14. ASCOP telemetering system.

The telemeter transmitter sequentially scans many transducer outputs at a rate of two per second. Each measurement is converted to a pulse length varying from 80 millisec for a 1-volt input (zero) to 400 millisec for a 5-volt input (full scale). During the scanning cycle the transmitter also sends automatic zero- and full-scale correcting signals that compensate for any errors or drift in the electrical system. The receiver synchronizes the transmitted time-multiplexed signals and converts each pulse back to a current between 1 and 5 ma dc proportional to the pulse length. A magnetic memory maintains this proportional current output during the time the telemetering system is scanning other inputs. Thus, the output from each measurement is a continuous current except for the short time it is being readjusted to a new value as called for by a change in the measured signal.

WHAT'S AVAILABLE IN ELECTRONIC PROCESS CONTROL SYSTEMS

Taylor Instrument Cos. (Rochester, N. Y.) recently introduced electronic control systems that use ac or dc transmission, depending on the process variable, and corresponding ac or dc recorders and controllers. Differential pressure and gage pressure (Figure 3) transmitters deliver ac signals from a differential transformer having a span of 0-200 mv at nominal line voltage. The span is electrically adjustable (without hazard in the field) over a 4-to-1 range. Such transmitters require four wires in the field, two wires carrying 6 volts for the transformer primary and two shielded wires carrying the 0-200 mv signal. Transmission of ac was selected because of the predominance of flow measurements in industrial applications and because a differential transformer permitted the design of a high-pressure seal with overrange protection and electrical span adjustment.

Taylor selected dc transmission for temperature measurements because in most cases thermocouples will be used. This means two wires in the field. The thermocouple millivolt output is changed to 1-to-5 ma dc current in a converter (previously available as part of Taylor's product line). This potentiometer-transmitter uses vacuum tubes. Other variables transmitted as dc are pH, dc tachometer, and strain measurements.

The recording of 1-to-5 ma dc transmitter signals is accomplished by passing the current through a 250-ohm resistance, producing a 0.25-to-1.25-volt dc signal. The dc voltage is converted to ac by a mechanical chopper and amplified; then the ac voltage drives a servomotor, a pen, and a rebalancing potentiometer to null the measured signal. Thus, at null the recorder pen is positioned in accordance with the value of the measured signal. For ac signals, the transformer output of 0-200 mv is compared with a signal from another differential transformer connected to the pen arm. The difference in these signals is amplified and drives a servomotor which positions a feedback transformer in a direction to null the error signal. Pen position then corresponds to the measured signal. All recorders are 100-percent transistorized. Figure 15 shows a two-pen recorder.

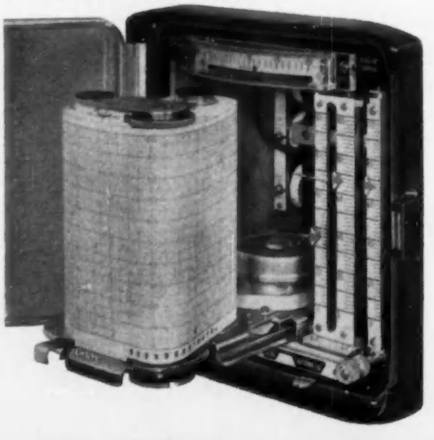
Control from ac signals is accomplished by comparing the output of the transmitter's differential transformer with the output of the set-point differential transformer. The resulting signal is converted to dc in a highly stable converter-amplifier whose output now ranges from 6 to 30 volts dc to feed the controller. Control from dc signals is obtained by comparing a 6-to-30-volt signal from the same potentiometer transmitter that feeds the 0.25-to-1.25-volt signal to the recorder. The transmitter output voltage is compared with a dc set-point voltage obtained from a reference voltage, and the difference voltage (the error signal) feeds a controller.

Controllers for ac and dc systems are essentially the same. Changing a printed circuit card converts the controller from ac to dc, as shown in Figure 16. The 6-to-30-volt error signal input is characterized by proportional, reset, and rate circuits, and the output current is 1-to-5-ma dc into a 10,000-ohm actuator load resistance. Controllers use two vacuum tubes (actually four amplification stages) because the high input resistance of the tubes makes it easier to obtain the large reset and rate time constants needed to meet a wide range of process dynamics. Taylor has two controller models.

The Taylor electronic control system design incorporates, as do other electronic product lines, unified plug-in construction. The controller mounts at the rear of the recorder; adjustments are available from both front and rear of the panel. The recorder contains cam-operated alarm circuits attached to the servo. The manual control station and set-point transmitter are separate plug-in units. For actuation, Taylor offers an electropneumatic valve positioner, designed for Class 1, Div. 1 areas, utilizing a balanced electrically operated armature to position the baffle of a two-to-one pneumatic booster relay.

The systems described contain many features, some unique to a particular system and some common to several. To avoid redundancy, the common features are only mentioned once throughout the descriptions. A lack of mention is not necessarily to be construed to mean that the system does not have that feature.

FIG. 15. Taylor's two-pen recorder.



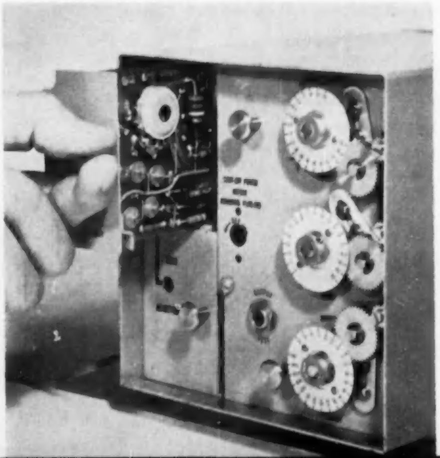


FIG. 16. Taylor's controller can be used for ac or dc signals simply by changing a printed circuit card.

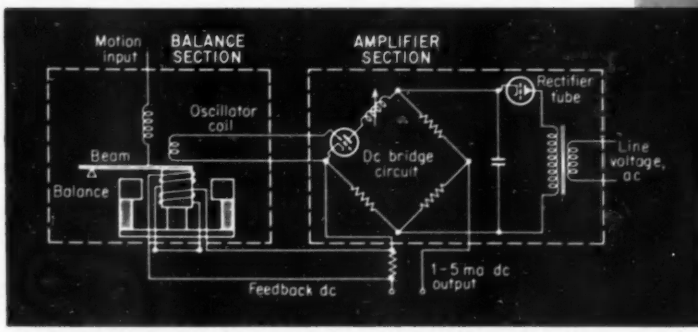


FIG. 17. Manning's Microsen displacement-type transmitter.

FIG. 18. Manning's recorder-controller.

MANNING AMERICAN-MICROSEN ELECTRONIC CONTROL SYSTEM

Manning, Maxwell & Moore (Danbury, Conn.) is one of the companies that fostered the use of miniature panel-mounted electronic control systems. The Manning system uses 1-5 ma dc for both measured (input) and control (output) signals. For displacement-type transmitters, the dc signal is obtained with the Microsen balance shown in Figure 17. Its operation and construction are similar to those of the error-sensing portion of the Manning controller illustrated in Figure 6B. The transmitters operate as follows: Measured pressure determines displacement of Bourdon tube or bellows, which rotates a hairspring and applies torque to a beam. The beam moves, changing oscillator inductance, and this in turn effects a corresponding change in the bridge's output current. A portion of the output current goes to the feedback coil, applying a torque opposing the spring torque until the beam becomes balanced at the new output current determined by the magnitude of the process pressure.

Four wires are needed for the transmitter just described, two for power (115 vac excitation) and two for carrying the signal back to the controller. The excitation need not come from the same source that powers the error-sensing circuit in the controller, but may come from a separate power source in the field.

Any dc current source between 1 and 5 ma serves as an input to a controller or recorder. The controller section of the recorder-controller, Figure 18, uses two transistors in the oscillator-amplifier and one duo-triode vacuum tube in the feedback amplifier that characterizes the error signal. The controller output is 1-5 ma dc feeding into a load (actuator or input to another controller for cascade control) of 3,000 ohms maximum. Set-point and manual control stations are individual plug-in units.

For recording, input current in another Microsen balance moves the beam and varies oscillator-current amplitude to change current flowing through the pen motor. This causes the motor rotor to position the pen. A mechanical linkage exerts a feedback force through a hairspring to balance beam forces and assure correct pen position. Two vacuum tubes operating in push-pull provide the current for the powerful pen-motor force. Indicators use direct-deflection meters, with both vertical and circular scales.

Manning's product line includes electropneumatic relays (general-purpose and explosion-proof), electropneumatic positioners, and electrohydraulic operators. Other items are ratio amplifiers, two-pen recorders, recording microammeters, and various temperature, pressure, differential pressure, linear flow, and level transmitters producing a 1-5 ma dc output.

FOXBORO ELECTRONIC CONSOTROL INSTRUMENTATION

The Foxboro Co. (Foxboro, Mass.) electronic control system features two different dc current transmission levels. The lower measurement level is 0.4-to-2.0 ma dc into 10,000 ohms, developed from a voltage-stabilized rotary differential transformer whose ac output is rectified to dc in the transmitter (Dynaformer) housing. This transmission level serves for Class 1, Group D, Div. 1 hazardous area requirements and for transmitting to receivers that require only small-power signals for their operation, such as controllers, data loggers, indicators, and servo recorders. For nonhazardous areas, for force-balance devices, and for receivers such as the pen-motor recorder, which need move power, a 25-to-1 current (magnetic) amplifier is added either at the transmitter or in the control room. This raises the current to 10-to-50 ma dc. Depending on where the amplifier and voltage stabilizer are located, a two-wire or four-wire system is available. All transmitters, including flow, Figure 19, include local indication through mechanical connection of the pointer to the Dynaformer.

Recorders, one- or two-pen, use the 10-to-50 ma dc signal to operate a powerful deflection motor without additional amplification, rebalancing, or linkages. The motor force is balanced against a calibrated spring. The motor inherently damps out violent oscillations, but adjustable hydraulic damping is included to minimize flow noise. The pen travels horizontally.

The controller, Figure 20, features front-of-panel adjustment of set-point, manual control, auto-manual transfer, and pull-out for side adjustment of control actions. Foxboro makes two standard models, a transistorized universal controller with various combinations of proportional, reset, and rate constants, and a magnetic amplifier flow controller with proportional and reset only. The Foxboro system does not use vacuum tubes anywhere. Plug-in design permits removal of the entire controller unit, removal of the control func-

tion generator with the manual control station remaining, or removal of the manual control station and its power supply. Two styles meet general-purpose or semihazardous area requirements.

The same current range for controller input and output facilitates installation of cascade control and ratio systems. Added versatility is available because the secondary (flow) controller need not have its own set-point: the corresponding signal comes from the output of the primary (temperature) controller. But if the set-point is included, a switch can break the cascade connection when desired and permit the secondary controller to have its set-point take over direct

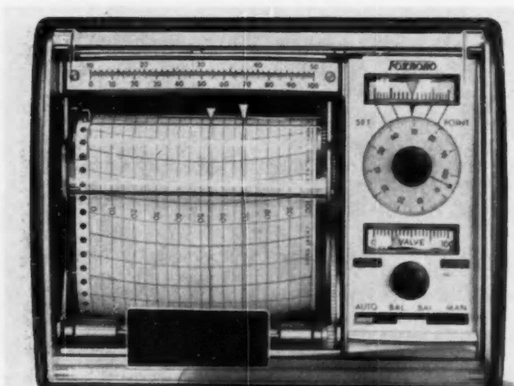


FIG. 20.
Foxboro's recorder controller.

FIG. 19.
Foxboro's flow transmitter features local indication.

control of the flow.

Foxboro's transmitter line includes a force-balance d/p cell using two wires with 10-to-50 ma output; motion-balance pressure and d/p using four wires with high or low level output emf resistance; and a combination of the company's Dynalog and Dynaformer for transmission of outputs from analytical instruments, magnetic flowmeters, and capacitance measurements.

For actuation, Foxboro has its own electropneumatic converter for pipe-mounting away from the valve's hazardous area, and it can supply a pneumatic positioner if needed. The company also furnishes Fisher Governor electrohydraulic operators for all-electronic systems where air is not available.

SWARTWOUT AUTRONIC CONTROL SYSTEM

The Swartwout Co. (Cleveland, Ohio) pioneered the development and application of all-electronic miniature control systems. Its system uses ac transmission (0.000 to 0.500 volt) from a differential transformer (for displacement-type transmitters) and controller-output circuit of 1-to-5-ma dc into a 12,000-ohm load. Swartwout controllers, Figure 21, feature plug-in installation at the rear of a mounting case containing the panel-mounted recorder, and a controller comprised of four separate plug-in printed-circuit cards: power supply, error amplifier, proportional band and reset actions, and rate action. With this arrangement, controllers can be made up to have only those functions needed at the outset, or can be modified later for changing process needs. Depending on the actions used, the controller can have two or three premium (ruggedized, long-life) vacuum tubes. The adjustments, a test jack for calibration and output signal indication, and a locking device to prevent removal of controller when the power is on, are at the back of the panel.

The excitation for the (differential transformer) transmitter must be supplied by the same source as that supplying the recorder and controller. This calls for four wires in the field. The four-wire arrangement assures that the transformers' phase angles are matched and prevents any voltage variation in the controller power source from producing a false error—now the variation has the same relative effect on both transformers. Should the controller be removed, the power switch restores the excitation to the remotely located transmitter for continued indication or recording of the process variable.

Swartwout indicators and recorders, Figure 22, are available with and without set-point stations. Recorders and indicators operate the same way except that the recorder has a vertical scale while the indicator has a circular scale. The 0.000-to-0.500-volt ac transmitter signal is compared in an ac amplifier with a signal from a differential transformer linked to the pen. Amplifier output is proportional to the difference (error) between measured signal and the existing pen position. Output goes to a phase-sensitive rectifier, which produces a dc voltage at the input of a dc power amplifier. The dc current output from the amplifier positions a rotary solenoid connected to the pen so that the solenoid force is balanced against a spring force. Through the differential-transformer pen-position feedback, the pen rapidly (but with adjustable speed) reaches the deflection called for by the measured process variable. A curved chart plate provides linear recording without mechanical linkage.

Swartwout manufactures a dc-to-ac converter as part of its product line. This converter changes dc measurements from such instruments as Beckman pH meters, tachometers, Ohmart density cells, and oxygen analyzers into the 0.000-to-500-volt ac signal needed for system compatibility. A modification of the converter serves for cascade control, since the dc current output of the master controller must be changed to ac voltage for input to the slave controller. The converter can feed a number of receivers.

Other emf and resistance-type transmitters produce the Swartwout ac signal. These include thermocouple and resistance thermometer converters for temperature, and an ac amplifier for strain gage measurements and narrow-span control from transmitters. For actuation, the company has a power relay (electropneumatic transducer for pneumatic valve operators) and a new valve operator using controlled vapor pressure to produce a large stem thrust.

MINNEAPOLIS-HONEYWELL ELECTRIK CONTROL SYSTEM

Minneapolis-Honeywell Regulator Co. (Fall River, Mass.) uses a true two-wire system, true in that no separate power source is needed, either in the field or in the control room, to excite the transmitter. Here, 4-to-20 ma dc current in the series-connected transmitter and receiver serves as the transmitter's excitation *and* signal. The 4-to-20-ma dc signal was selected as being consistent with reliable operation of transistors used in all components except the controller. A power supply (separate, or in the recorder or indicator) automatically delivers the right amount of current to an oscillator-magnet coil arrangement in the transmitter to balance the measured-variable torque on a beam. The power-supply current, now proportional to the measured variable, goes to the error-sensing circuit shown in Figure 6A.

For recording, Figure 23, the current also goes in series to a similar circuit, but here the signal is servo-positioned to drive the torque motor of a deflection-type recorder. Rectilinear (straight line) recording occurs because the arc described by the pen is compensated by a corresponding change in the spring force of a feedback spring connected between the pen and the balancing beam.

Controllers, Figure 24, are all-electronic units (no moving parts), employing vacuum tubes to get the high impedances needed for reset and rate time constants. An input signal (plus 10 to minus 10 volts) is obtained from the error-sensing circuit through internal wiring in the recorder or indicator housing. Controller output is 4-to-20-ma dc into 0 to 1,500 ohms. Controllers are available with and without rate action.

For cascade control, the set-point spring on the beam in the error-sensing circuit of the secondary controllers serves as a bias adjustment and another coil added to the magnet unit receiving the output signal from the primary controller acts as the set-point. Still other

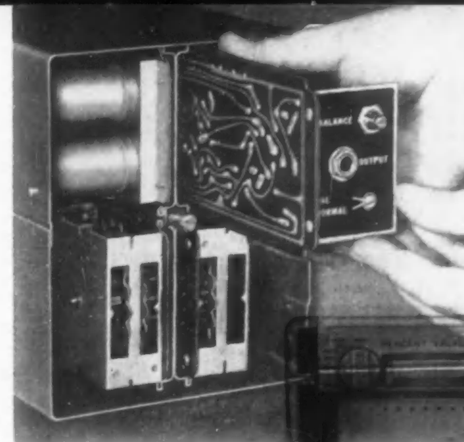


FIG. 21. Swartwout's controller is a unitized package of four plug-in components.

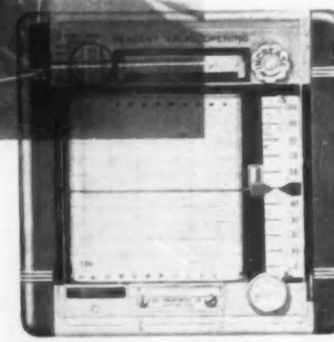


FIG. 22. Swartwout's recorder, with manual control station and set-point in the same box.

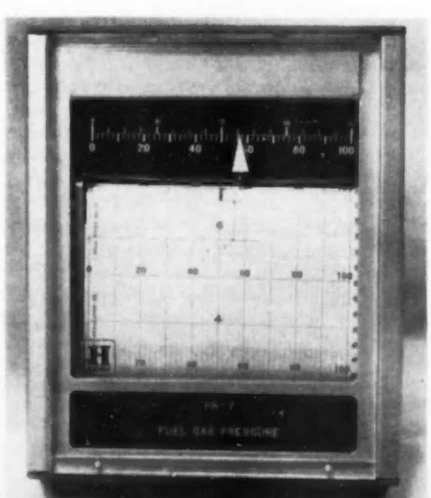
coils, all working in the 4-to-20-ma range, can provide adding, reversing, and biasing functions. The Honeywell line will eventually have simple electrical units performing square-rooting, multiplying, dividing, adding, and subtracting which can be attached without special concern for mechanical interconnection or location in the system.

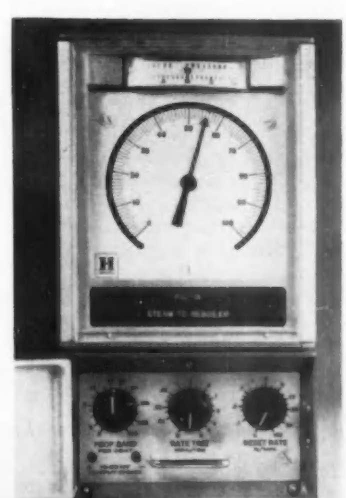
For indication, Honeywell uses simple milliammeters, and servo indicators with or without control station and with or without cascade. The present line of components includes current-to-pressure and pressure-to-current transducers for application in hybrid electronic-pneumatic systems and for valve actuation. Among transmitters available for and compatible with the Honeywell system are millivolt-to-current, process pressure-to-current using bellows or Bourdon tubes, differential pressure-to-current, and liquid-level (displacement)-to-current.

For actuation, Honeywell uses an electropneumatic valve operator similar to its current-to-pressure transmitter. It features pipe or valve mounting, weatherproof and explosion-proof case (if desired), quick-disconnect electrical connections, and self-sealing pneumatic quick-connect plugs to prevent bleeding of air. At a later date, Honeywell plans to market two different sizes of electrohydraulic valve actuators with stem positioning.

FIG. 23. Minneapolis-Honeywell's electronic recorder, left.

FIG. 24. Minneapolis-Honeywell's electronic controller, right.





for valves up to 2 in. and up to 10 or 12 in.) and an electropneumatic valve positioner. The actuators will operate from Honeywell's 4-to-20-ma dc signal.

LEEDS & NORTHRUP ELECTRONIC CONTROL SYSTEM

The L & N electronic control system, Figure 25, will be available in 1959. For flow, level, and pressure transmitters, the company uses a null magnetic balance arrangement which generates a 1-to-5 ma dc signal. The transistorized transmitter operates on the basis of maintaining a constant electromagnetic field, but the core displacement—proportional to the measured variable—changes the field. A feedback coil then automatically adds a balancing field, and the current required to do this is proportional to the measured variable. For data handling, the transmitter produces a 0-to-4 ma dc signal, so that extra circuits are not needed to suppress zero. The temperature transmitter electronically converts an emf signal to the 1-to-5 ma dc signal.

The controller has the usual three modes and is transistorized. It functions on the basis of voltage comparison developed by the input signal from the transmitter. One feature of the L & N controller is, within one station, cascade control with adjustable low

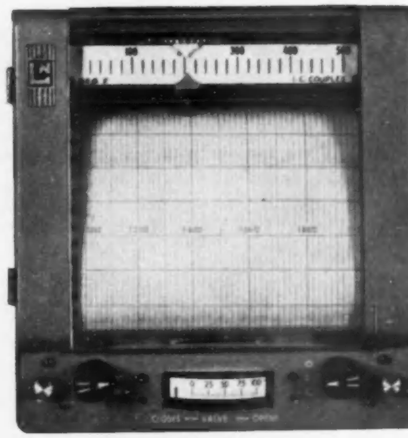


FIG. 25. Leeds & Northrup Automax controller and Speedomax M recorder.

limit and span of secondary control point. A switch cuts out the primary controller when desired for straight flow (secondary) control, which has its own manual adjustable set-point. The station also has automatic-manual transfer.

The recorder is a miniature Speedomax, featuring a high-torque servo powerful enough to operate the pen, alarms, and a retransmitting slidewire.

ELECTRICALLY SIGNALED ACTUATORS

Figure 1 shows many possible arrangements of electronic instruments and, at ACTUATION, the many ways of changing the controller electrical output to a powerful valve thrust. The electric signal controls air pressure, oil pressure, electric current, and gas pressure.

Makers of control systems also produce some actuating devices, and these, of course, operate from the dc-current output range from their controllers. These makers may be willing to modify the electrical portion of the actuating devices to accept signals from other makes of controllers. Other makes of actuators, transducers, and positioners can easily accommodate signals from any controller. In fact, several of these products already are featuring compatible input circuits.

Electropneumatic transducers and positioners

These devices modulate air pressure driving pneumatic valve actuators. Some transducers (relays) operate as follows, Figure 26: A moving coil in the field of a permanent magnet receives the controller signal and through a lever arrangement transmits a force to a small diaphragm-pilot valve in the air portion of the relay. The air-loading pressure in the pilot balances the magnetic force and an internal connection carries this same pressure to the lower side of a large diaphragm in a high-capacity booster relay. A booster pilot builds up the same pressure on the top of the large diaphragm, so that the loading pressure (the output of the relay) is now proportional to the input current. The relay has thus taken a low-power electrical signal and transduced it into a large-capacity air pressure output for fast valve actuation.

Other electropneumatic transducers use a flapper-nozzle arrangement, in which the input current goes to a movable coil receiving the controller output current. An increase in current develops a force on the flapper-beam, moving the beam closer to the nozzle. As the nozzle closes off, less air bleeds through, increasing output air pressure. The beam moves until the force produced by input current is equalized by the force produced by air pressure acting through the nozzle area at the beam. The output pressure going to the valve is now proportional to the input current. For reverse action, that is, when the valve is to open with an increasing signal, the input polarity is reversed and the zero spring is set so that at minimum current the transducer output is 15 psi.

Electropneumatic valve positioners combine the function of a transducer and a positioner. One, the Fisher Governor E-Positrol, Figure 27, is actually made up of two separate components, an e-p transducer and a positioner ordinarily used for pneumatic-valve actuation. Positioning assures that the valve stem reaches the position commanded by the input signal to compensate for any valve-unbalance forces from, for instance, friction in the valve. Positioning is accomplished by means of feedback between the valve stem and the controller signal.

The Moore Products Co. E/P positioner was shown previously in Figure 12. Here force balance continuously exists between the electromagnetic force from the input signal and the range spring from the position

of the valve's piston or diaphragm. Any change in forces is detected by the measuring pilot, which controls the pressure in the actuator's operating chamber and positions the piston or diaphragm.

Split-ranging, controlling two valves from one controller, can be accomplished easily with electropneumatic positioners. As an example, if resistance for a standard positioner is 3,000 ohms, then each valve's positioner will have a resistance of 1,500 ohms. The positioners are in series with the controller output. One positioner will be effective over the 1-to-3-ma range, and the other will respond—with the aid of a suppression spring—only to signals between 3 and 5 ma.

Electrohydraulic valve actuators

Electrohydraulic actuators use oil pressure to deliver fast, large stem thrusts. Again, the actuator input is the controller signal. This type of actuator is self-contained: the hydraulic pressure is generated by a continuously running motor and pump. The motor power is obtained from any field source, often 115 vac. Figure 28, a schematic of the unit made by Mason-Neilan, shows one type of electrohydraulic actuator. When a control signal increases (or decreases) it appears as an error voltage at the summing amplifier. This error actuates the torque motor and repositions the pilot valve, which directs hydraulic fluid to one side of the ram, forcing it to move. The ram drives the valve stem, as well as the core of a differential transformer whose output is a feedback voltage, and this voltage is then converted to a dc voltage opposing the input signal. This decreases the error and the ram continues to move until the signal voltage and the feedback voltage equalize. At equalization, the torque motor and pilot valve assume their centered positions.

Fisher Governor electrohydraulic actuators, Figure 29, use two flapper-nozzles driven by a force motor to change the hydraulic pressure on both sides of a cylinder. When an unbalance pressure exists, having been called for by a new control signal, the cylinder moves and at the same time delivers a feedback force balancing the flapper-nozzles so that the valve stem is in the position dictated by the electrical signal.

GPE Controls, Inc. (formerly Askania) makes the jet-pipe electrohydraulic valve actuator in Figure 30. Here the moving coil receiving the signal moves a jet pipe through which high-pressure oil is being pumped. Each side of a cylinder is connected to ports to which the pumped oil is directed. When the jet pipe moves the differential pressure across the cylinder changes and the cylinder moves accordingly to position the valve. A feedback lever-spring equalizes the forces acting on the jet pipe as it reaches its new position. The jet pipe returns to its neutral position and the differential pressure across the piston establishes a balance.

Electrohydraulic operators can be obtained with a locking device that keeps the stem at its last position following failure of motor power or controller signal.

All-electric valve actuators

All-electric valve actuators use low-inertia reversible motors and a rack and pinion to drive the valve stem. A diagram of Norwood Controls' newly released electric valve positioner is shown in Figure 31. The summation circuit compares the current output from a feedback element geared to the valve stem with the input current from the controller. The difference, amplified by a transistorized preamplifier, actuates a three-position contactor which controls the direction of the ac drive motor until the error is within the dead zone or neutral position of the contactor. Limit switches prevent excessive stem overtravel and seating forces. The positioner has two parts: the amplifier mounted in the control room and the actuator mounted in the field. The two are connected with a six-conductor cable. The amplifier requires 32 milliwatts for operation, at any current between 0-to-4 ma dc and 2-to-6 ma dc. With simple adjustments, it can be set to the 1-to-5 ma signal produced by several makes of controllers.

Conoflow also makes an all-electric actuator. Ap-

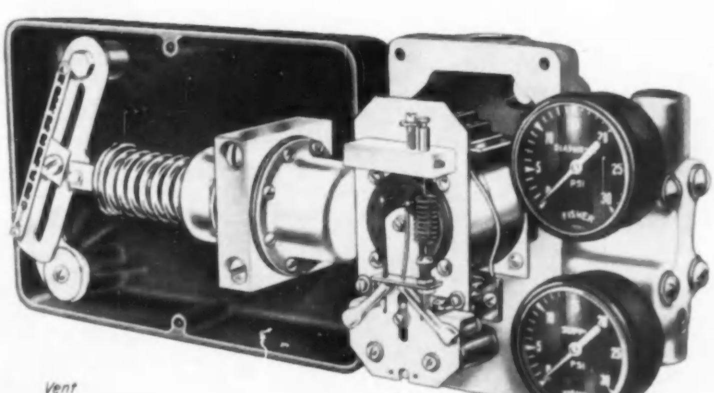
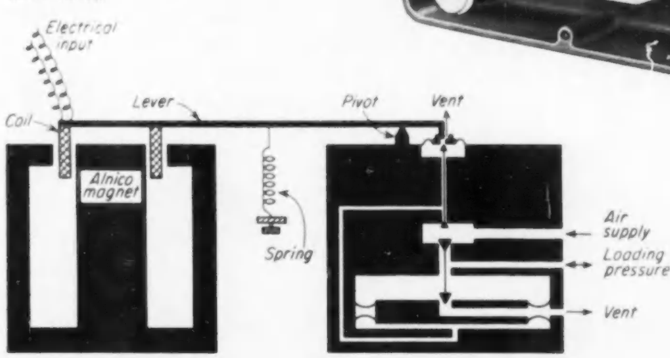


FIG. 27. Fisher Governor's E-Positrol typifies an electropneumatic positioner for operating pneumatic valves.

FIG. 26. Swartwout's power relay typifies electropneumatic transducers for operating pneumatic valves.



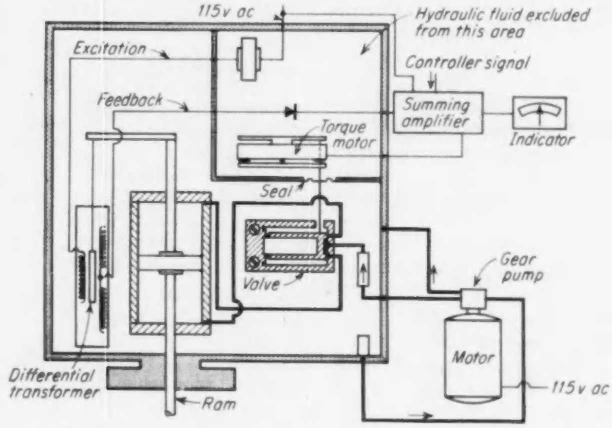


FIG. 28. Schematic of Mason-Neilan electrohydraulic actuator.

plied to a current-sensitive detector, the controller output signal of this actuator develops a force which produces a small displacement of the core of a differential-transformer motion detector. The transformer output goes to a relay amplifier which senses the direction of signal change and drives a reversible ac motor in the correcting direction. A range spring feeds back stem position to the current detector, and the actuator continues to correct until the desired stem position—as called for by the controller signal—is reached.

The relay amplifier uses two vacuum tubes. Nine wires run from the amplifier in the control room to the actuator; two to carry the controller signal, two to carry excitation to the motion detector, two to carry the displacement signal back to the relay-amplifier, and three to the reversible motor.

Electrovapor actuators

This is a new concept in actuation, developed recently by Swartwout; it uses controlled vapor pressure generated by electrical-heating vaporization of a self-contained fluid. The electrical signal controls heat release to balance heat input for the desired stem thrust. Internal stem-position feedback is included. Illustrations are contained in CtE, October 1958, page 117.

FIG. 29. Fisher Governor's electrohydraulic actuator with cover removed.

Standby power and wiring techniques

Some users may require an emergency source of power on instant standby, ready to supply the electronic instruments should a failure of normal plant power occur. George C. Johnson of Socony-Mobil Oil Co. will describe in a forthcoming issue of Control Engineering some general aspects of standby power. This will be a checklist to determine whether a standby source is needed, and if so, the several ways to get reliable standby power at the plant site.

In the same issue, William Carmack of The Fluor Corp., Ltd., describes two wiring methods for electronic control systems. The wiring suggestions cover both ac-dc systems and dc-dc systems and are followed by the tabulated results of a survey showing the relative costs of wiring for small-plant, short-run, scattered-locations of valves and transmitters; and for large-plants, long-runs, close-locations.

FIG. 30 GPE Controls' jet-pipe electrohydraulic valve actuator.

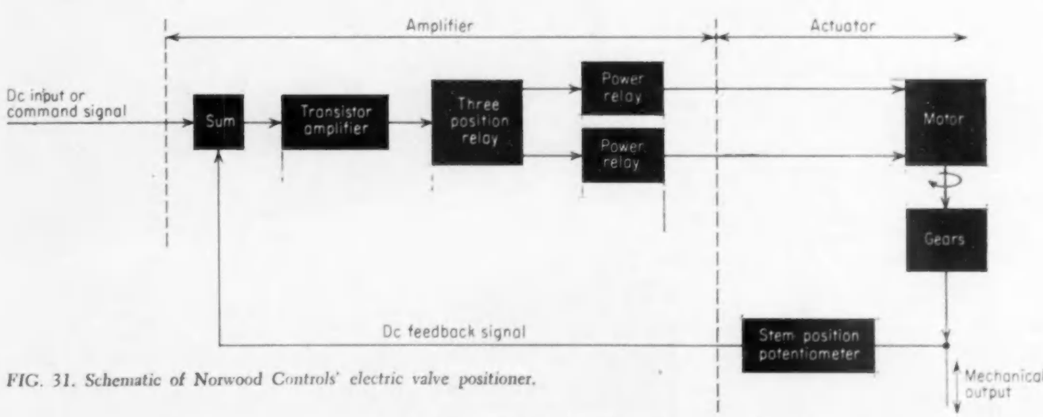


FIG. 31. Schematic of Norwood Controls' electric valve positioner.

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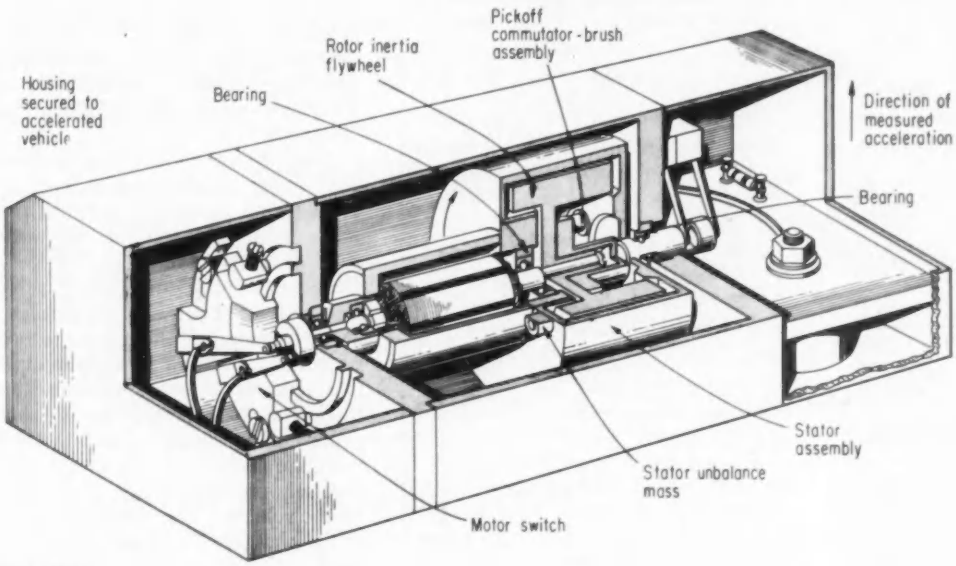
FIG. 1. Torsion-reaction double-integrating accelerometer.



A NEW Double-Integrating Accelerometer

KENNETH E. POPE
Integrated Dynamics Div., Globe Industries, Inc.

THE GIST: Measuring acceleration in inertial guidance systems is not an end in itself. To be of use, the measured acceleration must be integrated at least once—to give vehicle velocity—and possibly twice—to give distance traveled and vehicle position. There are many non-integrating accelerometers that will give an output accurate to 0.1 percent or better of full scale, but inaccuracies are introduced in the electronic integration process that must follow—as much as 3 percent overall velocity error and 5 percent overall distance error.

The torsion reaction accelerometer gets around this excessive integration error by measuring acceleration and performing two time integrations in the basic accelerometer. Current models are accurate to within 0.5 percent, and an accuracy of 0.1 percent does not seem beyond reach. Too, this accelerometer simplifies the system by eliminating two stages of electronic integration and by providing a pulse-train output signal. Telemetering is easy, since velocity is proportional to pulse frequency (and inversely to pulse width) and distance traveled is proportional to the number of pulses.

The torsion reaction accelerometer consists of a modified permanent magnet dc motor with a high-inertia rotor system, Figure 1. The rotor, stator, and fixed-housing assembly is designed so that the rotor can rotate within the stator, and the stator can rotate relative to the housing. An unbalance mass attached to the stator assembly converts the latter into a pendulum, which, when subjected to an acceleration, rotates to close a motor switch.

The motor switch (located to close after a small clockwise rotation of the stator assembly) energizes the motor upon sustained acceleration, and the starting torque reaction of the motor stator to the flywheel rotor opposes the rotation of the stator produced by housing acceleration. This causes the stator to move in a counterclockwise direction, opening the switch and deenergizing the motor. But if the housing is still being accelerated, the switch closes again and the cycle repeats about 200 times per sec.

It will be shown later that the speed of the motor

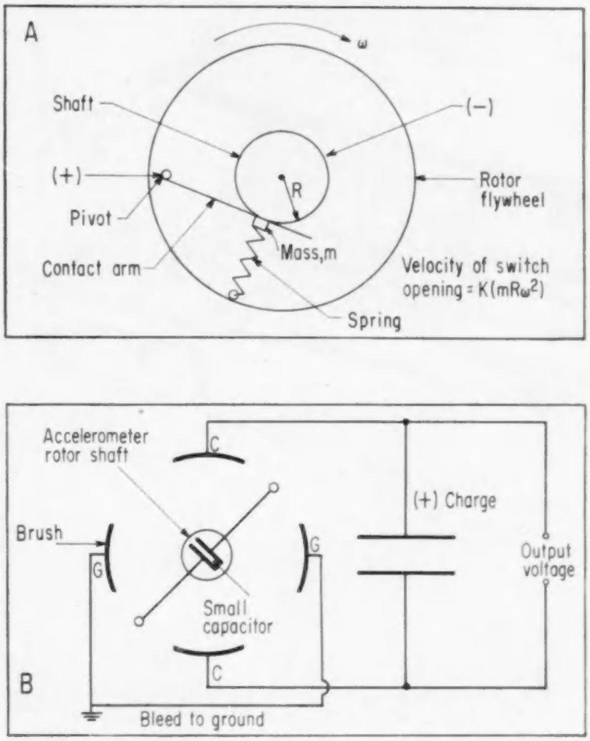


FIG. 2. Governor-type device, A, opens circuit at preset vehicle velocity. Voltage across large capacitor in B is inversely proportional to number of rotor revolutions.

rotor, at any instant after time zero, is proportional to vehicle velocity at that instant, and that the total number of rotor revolutions is proportional to the distance the vehicle has traveled. The problem then becomes one of measuring rotor speed and angular movement.

A typical unit is 2¼ in. sq by $5\frac{3}{16}$ in. long, and weighs 20 to 30 oz. The maximum error can be held to plus or minus 0.5 percent for input signal ranges not to exceed a maximum of 1,000 times the smallest signal level to be integrated. By varying the physical configuration, units can be made to measure linear accelerations from 10^{-2} to 10, ½ to 50, and 1 to 100 g's and to integrate velocities from 20 ft per sec to 16,000 ft per sec (about 11,000 mph). The time period for which the unit can measure depends on the maximum acceleration.

Signal output techniques

There are several methods of making available signals that are proportional to accelerometer rotor speed and rotor angular movement. These can be classified as switch closures, pulse-train outputs, and continuous analog signals. Figure 2A shows a simple governor-type device that gives a switch opening when the vehicle in which the accelerometer is mounted reaches a preset velocity. Two of these devices—giving either a switch closure or a switch opening—can be included in one accelerometer. They are useful for initiating velocity-dependent functions.

A pulse-train output can be obtained by using a simple commutator-brush pickoff, as shown in Figure 1. The total number of pulses is proportional to the total angular travel of the rotor and, in turn, to the total distance traveled by the vehicle. Pulse-train frequency is proportional to vehicle velocity up to a frequency of about 2 kc. Note also that the velocity at any instant is inversely proportional to pulse width. In addition to simplifying the telemetering requirements, this output form lends itself to automatic data reduction. This appears to be the most promising of the techniques that have been tried.

Figure 2B shows a way to obtain an analog voltage inversely proportional to the total distance traveled by the vehicle. The large capacitor is given a known initial charge. The small capacitor attached to the rotor is charged by the large capacitor each time the C brushes are contacted, and discharged to ground when the G brushes are contacted. Thus the remaining voltage across the large capacitor is inversely proportional to the number of rotor revolutions and to vehicle travel.

Presently under development is a digital-to-analog converter that will sum pulses to give a voltage proportional to distance, and a frequency-to-analog converter that will give a voltage proportional to the frequency of the signal and consequently proportional to the velocity. These systems are expected to find application where visual display of velocity-distance information is desired, such as in go/no-go warning systems on piloted aircraft.

Where to use it

Because of the ease of telemetering data, this type of accelerometer is useful in sled acceleration and retardation tests, free-flight rocket engine tests, and other applications where accurate knowledge of acceleration, velocity, or distance with respect to time is required. Data can be recorded on magnetic tape and automatically reduced to yield distance-time, velocity-time, and acceleration-time point-to-point analog plots.

Other major applications are in guidance systems or in the control of auxiliary functions in missiles and piloted aircraft. For example, many missiles are armed close to the desired firing point. The arming function is often initiated by a timer, with the flight time based on an average velocity determined from many test firings. The difficulty is that rocket parameters are not constant from engine to engine and for any given flight the actual velocity may vary considerably from average. A double-integrating accelerometer solves this problem by keeping track

NOMENCLATURE

M_{rs} = motor torque
F_{exs} = external torques acting on stator other than torques due to acceleration or rotor reaction
F_{sr} = friction torques between stator and rotor
F_{sh} = friction torques between stator and housing
$\tau_1, \tau_2, \tau_3, \tau_4$ = torques acting on stator during four quarters of oscillation
M = mass of stator unbalance
A = acceleration of vehicle in measured direction
A_n = acceleration normal to A
L = lever arm of MA
L_{eff} = effective lever arm
θ = angular motion of stator from null point
I_r = rotor inertia
α_r = rotor angular acceleration
ω_r = rotor angular velocity
θ_r = rotor angular motion
C_1 = lumped design constants
E = effective error torque

of the distance the missile travels, so that there is no need to depend on flight time and average velocity to determine the proper arming point. Since the accelerometer also yields instantaneous missile velocity, it is also possible to include automatic self-destruct or continue-to-arm systems based on actual rocket performance and the knowledge that the missile is still directed toward the target and hasn't deviated from its intended course.

Special accelerometers with a threshold sensitivity of 0.001 g and a maximum acceptance level of 10 g's have been developed for use in missile guidance systems. Applications along this line include short-interval stable platforms, where the desired flight parameters are prerecorded on tape. Integrator output is compared to the tape and corrective signals for the flight control system are generated by differential frequency or differential pulse-width techniques.

Piloted-aircraft applications are similar to those in missiles: specific uses include vertical velocity determination during hard-landing tests on prototype aircraft, vertical velocity determination during night landings of water-based craft, and various engine and aircraft performance tests during development. An interesting new development is a go/no-go takeoff indicator that tells a jet pilot whether he should continue or abort takeoff depending on aircraft performance prior to the arrival at the point of no return on the runway.

Figure 3 shows an unusual application that has nothing to do with flight control, but is useful in computer applications. It is an analog-to-digital voltage integrator in which input torque is furnished by a torque generator rather than by accelerating the housing.

Operational analysis

The rotor and stator are free to rotate; hence, forces acting on these elements will result in torques that cause rotation, Figure 4.

While applied torque MLA starts the stator oscillating, the actual torque causing stator rotation is the summation of all torques acting on the stator at any instant. During the first quarter cycle of oscillation (assuming the stator is in the unenergized position) the torque is equal to

$$\tau_1 = MLA \cos\theta - F_{sh} + MLA_n \sin\theta - F_{sr} \pm F_{exs} \quad (1)$$

where F_{sh} is a frictional torque acting between stator and frame, A_n is the acceleration, if any, perpendicular to the acceleration being measured (generally termed cross-axis acceleration), F_{sr} is the frictional torque acting between stator and rotor, θ is $\frac{1}{2}$ of the angle through which the integrating element (stator) moves (generally 3 deg), and F_{exs} is the sum of other unaccounted for torques acting on the stator.

During the second quarter cycle of the first oscillation, the torque becomes

$$\tau_2 = MLA \cos\theta - F_{sh} - MLA_n \sin\theta - F_{sr} \pm F_{exs} - M_{rs} \quad (2)$$

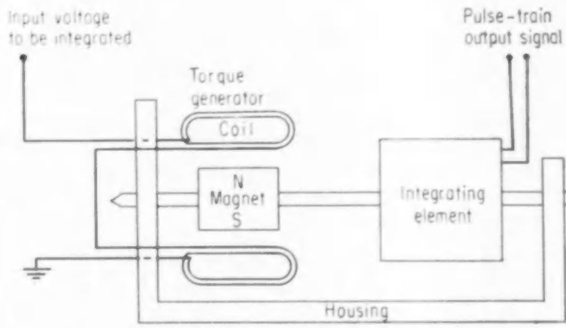


FIG. 3. Accelerometer used as electromechanical integrator.

where M_{rs} is a motor torque generated by the motor when the null-sensing switch closed at the beginning of the second quarter cycle. During the third quarter of the first oscillation, the torque on the stator takes the form

$$\tau_3 = MLA \cos\theta + F_{sh} - MLA_n \sin\theta + F_{sr} \pm F_{exs} - M_{rs} \quad (3)$$

And in the last quarter of the oscillation

$$\tau_4 = MLA \cos\theta + F_{sh} + MLA_n \sin\theta + F_{sr} \pm F_{exs} \quad (4)$$

Since the term $MLA_n \sin\theta$ appears in two quarters with a positive sign and in two quarters with a negative sign, the total effect of this component over a full oscillation is zero, assuming the oscillation excursion is equal about the null point. F_{exs}, caused

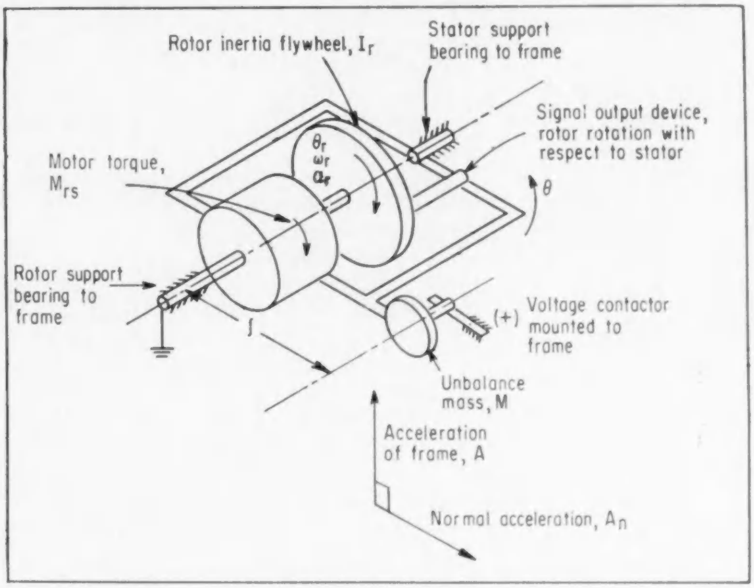


FIG. 4.
The mechanics of accelerometer operation. Simple analysis shows that rotor velocity is proportional to vehicle velocity, and rotor angular displacement to distance traveled by vehicle.

by imperfections in balancing and alignment, is difficult to determine, but precision balancing and machining keep it small. Since the dither angle θ is about plus or minus 1.5 deg, $L \cos \theta$ can be replaced by some average lever arm called L_{eff}.

The unbalance mass returns to its original position; therefore, the torque acting during the second and third quarters of oscillation is equal and opposite to the torque acting during the first and fourth quarters. Substituting in Equations 1 to 4 and summarizing yields:

$$\text{1st } \tfrac{1}{4} \text{ cycle} \ldots\ldots \tau_1 = ML_{eff}A - F_{sh} - F_{sr} \tag{5}$$
$$\text{2nd } \tfrac{1}{4} \text{ cycle} \ldots\ldots \tau_2 = ML_{eff}A - F_{sh} - F_{sr} - M_{rs} \tag{6}$$
$$\text{3rd } \tfrac{1}{4} \text{ cycle} \ldots\ldots \tau_3 = ML_{eff}A + F_{sh} + F_{sr} - M_{rs} \tag{7}$$
$$\text{4th } \tfrac{1}{4} \text{ cycle} \ldots\ldots \tau_4 = ML_{eff}A + F_{sh} + F_{sr} \tag{8}$$

Summing Equations 5 and 6, and 7 and 8, and equating the sum gives

$$2ML_{eff}A - 2M_{rs} = 2ML_{eff}A - 2M_{rs} = 0 \tag{9}$$

so that the average M_{rs} is zero. During the second quarter

$$M_{rs} = ML_{eff}A - F_{sh} - F_{sr} + I_r\alpha_r$$

and during the third quarter

$$M_{rs} = ML_{eff}A + F_{sh} + F_{sr} + I_r\alpha_r$$

so that the average M_{rs} is

$$M_{rs(avg)} = \frac{2ML_{eff}A + 2I_r\alpha_r}{2}$$

and since the average M_{rs} is zero, then

$$ML_{eff}A + I_r\alpha_r = 0$$

$$A = \frac{-I_r\alpha_r}{ML_{eff}} \tag{10}$$

If the stator moves with exactly simple harmonic motion, then the supposition that $MLA_n \sin \theta$ is equal to zero over any complete oscillation is true. However, the oscillation time interval is generally not equal on both sides of null, depending on the magnitude of torque available from the motor over the magnitude of $ML_{eff}A$. Consequently, an error is introduced unless the unit is mounted with its pivot axis parallel to the cross-axis acceleration A_n. The final errors, E, appear in the form of torques. Therefore,

$$A = \frac{-I_r\alpha_r}{ML_{eff}} + E$$

$$A = C_1\alpha_r + E \tag{11}$$

Integrating both sides of Equation 11 between the limits t_o and t_1, where t_o equals 0, gives

$$V = C_1\omega_r + Et_1 \tag{12}$$

where V is vehicular linear velocity, and ω_r is rotor angular velocity. Integrating Equation 12, in turn, yields

$$d = C_1\theta_r + \frac{Et_1^2}{2} \tag{13}$$

where d is the linear distance traveled by the vehicle and θ_r is the angular distance turned by the rotor. This proves the proportionality between rotor speed and vehicle velocity, and between rotor angular position and vehicle distance traveled assumed earlier.

By minimizing the effective error torque E, linearity accuracies of 0.1 percent have been achieved for the first and second time integrals of acceleration for time intervals up to 240 sec.

Electronic Standards for Industrial Equipment

General Motors Electronics Committee

The following standards have been extracted from "Electronic Standards for Industrial Equipment" prepared by a task group of the General Motors Plant Engineering Electronics Committee to insure safe and dependable operation of electronic equipment in GM's manufacturing processes. The standards listed here are selected from a considerably larger original list so that the numbers do not correspond with those in the complete standard. The exact wording of the standards listed has been retained, however.

GENERAL

1. The purpose of these Electronic Standards is to provide detailed specifications for the construction and application of electronic apparatus to industrial equipment, which will promote:
   a. Safety to personnel
   b. Uninterrupted production
   c. Long life of the equipment
   d. Ease and low cost of maintenance
2. Wherever electronic and electrical equipment are employed together, these Standards shall apply only to the electronic equipment and shall be supplemental to the JIC Electrical Standards for Industrial Equipment.

STANDARDS ON CONSTRUCTION PRACTICE

General

1. The use of subchassis construction is recommended.
2. Subchassis which have the same function and rating and are electrically identical shall be interchangeable.
3. Test points shall be brought out for checking essential wave forms and voltages where terminals are not otherwise provided.
4. Test points for measuring voltages in excess of 1,000 volts shall be provided with voltage dividers.
5. Drawers or other plug-in chassis shall be guided and locked.
6. All hardware shall be plated or of a noncorrodible material.
7. Lock-washers or other locking devices shall be used.
8. Resilient washers shall be used whenever plastic, phenolic, porcelain or other brittle materials are bolted in assembly.
9. Control knobs shall be fastened by two set screws or other equivalent means.

Soldering and electrical connections

1. A solder with a noncorrosive flux, such as rosin, shall be used.
2. All parts shall be "tinned" before soldering unless the part is specifically plated to insure a good soldered joint (e.g., "AN" type connectors having gold-plated contacts).
3. All parts shall be cleaned prior to soldering.
4. A minimum amount of solder shall be used on all connections except tubular or cup-type terminals. For tubular or cup-type terminals, the cavity shall be filled with solder.
5. Insulation shall not be damaged by soldering.
6. Components which may be damaged by heat when soldering shall be suitably shielded from the heat during the soldering operation.
7. Compression-type lugs and connections may be used. All other connections shall be soldered.

Interconnection cables and connectors

1. The external covering on the cable shall be oil-resistant, such as neoprene, polyvinyl chloride, or equivalent.
2. When connection from the shield to both connector pin and the cable clamp is indicated, the shield shall be connected directly to the pin and the pin connected to the cable clamp by hook-up wire. Connection to the clamp shall be by a lug.
3. The cable clamp of the connector shall be clamped on the outer insulated covering of the cable. The cable shall be built up if necessary, to insure good clamping.
4. When more than one plug and receptacle are used and where interchange of plugs may result in injury to personnel or damage to equipment, they should not be interchangeable.
5. The energized portion of the circuit shall be connected to the female end of plugs and receptacles.

Wiring

1. General-purpose hook-up wire shall consist of stranded tinned copper not less than AWG 22, with thermoplastic insulation.
2. Shielded cable, single or multiple conductor, shall consist of stranded tinned copper not less than AWG 25 size for single conductor wire used in

subassemblies and not less than AWG 22 for all other uses. The wire or wires shall have thermoplastic insulation, metallic shield, and an oil and moisture resistant covering, such as vinyl plastic.

3. All conductors and multiconductor cable used on industrial equipment shall have insulation rated at 600 volts, except for the following:
   a. The internal wiring on electronic panels shall have insulation adequate for the voltage on that wire. In no case shall insulation less than 300 volts be used.
   b. Special wiring of sufficient insulating capacity to protect equipment and personnel shall be used when external wires and cables must carry an excess of 500 volts.
4. Current carrying capacity. The values of current ratings (amperes) of conductors given in Table I are for normal use. These values must be modified for special insulations and locations.
5. All wires and cables shall be secured and protected to prevent strain on the wire termination or fraying of the insulation.
6. The internal wiring of electronic equipment shall conform to the color code listed in Table II, which is based on the EIA code. This conformance shall be indicated on the schematic diagram and on the equipment. Multicolored wires shall be indicated by two or more abbreviated symbols (e.g. Wh.-Rd.). The base color shall be the first color appearing in the series.

Printed circuits

1. Plastic boards with copper laminate on one or both sides may be used in place of conventional wires within electronic units.
2. The base material of the plastic board shall be grade XXXP or equivalent.

TABLE I—CURRENT CARRYING CAPACITY OF WIRES

AWG wire size	Current rating, amperes
22	3
20	5
18	6
16	8
14	12
12	16
10	24

TABLE II—WIRING COLOR CODE

Base color	Abbreviation	Circuit
Black	Blk.	Grounds, grounded elements
Brown	Brn.	Heaters or filaments, off ground
Red	Rd.	Power supply high B plus
White-Red	Wh.-Rd.	Power supply low B plus
Orange	Or.	Screen grids
Yellow	Yel.	Cathodes
Green	Gn.	Control grids
Blue	Blu.	Plates
Violet	Vil.	Miscellaneous
Grey	Gy.	AC power line
White	Wh.	Power supply B minus

TABLE III—CURRENT CAPACITY OF PRINTED WIRES

Line width, in.	Amperes	Ohms/in.
1/4	3	0.0009
1/8	1.5	0.0018
1/16	0.75	0.0035
1/32	0.40	0.007

TABLE IV—VOLTAGE RATING OF PRINTED WIRES

Voltage*	Minimum line separation, in.
0–150, incl.	1/32 (0.031)
Above 150–300, incl.	1/16 (0.062)
Above 300–500, incl.	1/8 (0.125)
Over 500	0.0003 in. per volt

*Maximum peak voltage during normal operation.

3. Plastic boards shall not be less than $\frac{1}{16}$ in. thick.
4. Copper shall be 100 percent International Annealed Copper Standard (IACS) and no thinner than 2 oz per sq ft (copper 0.0027 in. thick).
5. Bond strength shall be not less than 700 lb/sq-in.
6. Currents for 0.0027 in. thick copper shall not exceed values shown in Table III.
7. Line width shall not be narrower than $\frac{1}{32}$ in.
8. Line separation shall be in accordance with Table IV.
9 Sharp corners should be avoided.
10. Lands shall be employed wherever components or external circuits are used.
11. Printed circuit boards should be protected from deposits of conducting dust.

Mounting and clamping

1. Mounting hardware shall be designed to facilitate replacement of parts and assemblies.
2 All miniature tubes shall be held in place by shields or clamps. All other tubes not mounted in an upright position shall be clamped.
3. Transistors shall be mounted in sockets where practicable. When transistors are mounted on heat sink or other special mounting, wires shall be connected to a terminal point to facilitate replacement.
4. Rivets and welds shall not be used to mount components.

STANDARDS ON GROUNDING

1. All exposed metal parts shall be at ground potential.
2. Where the equipment is portable and the power connection is by means of a plug and flexible cable, the plug shall be provided with a grounding pole. The grounding pole shall make connection before any current carrying poles are made. The grounding pole connection shall not be broken until all current carrying poles are broken.
3. A copper or other corrosion-resistant conductor shall be used for grounding purposes.
4. The size of the ground conductor shall be equal to the power conductors to the equipment.

Digital Computers Grow in Great Britain

The development and present status of the digital computer art in England are here critically surveyed by specialists who have lived with the problems. This month, Britain's first computer show will exhibit for the first time some of the equipments discussed. They indicate, among other things, that the eyes of the British computer industry are turning toward the world market.

K. TYLDEN-PATTENSON
G. M. E. WILLIAMS,
P. E. Management Group, Ltd., London

Although the development of digital computers in Great Britain has lagged considerably behind that in the U.S., the computer exhibition to be held in London this month will show that the British manufacturers can now meet the challenge in America and in some instances even offer equipment not yet available there. The slower growth in Great Britain may be attributed to the innate caution of the average British company concerning investments in so-called newfangled ideas, to the recent credit squeeze, and to the size of the average firm which, with the exception of a few large combines, is small compared with its American counterpart.

The rate at which computers have been installed can be seen from Table I. This table excludes electronic calculators without internally stored programs, even though they may be capable of being programmed, and therefore omits such machines as the British Tabulating Machine Co.'s 542, 550, and 555, the IBM 604 and 626, and the Powers Samas EMP and PCC, for all of which there is a growing demand.

The ratio of computers used for data processing and scientific work is at present the reverse of that in America, but within the next year the data processing field will exceed the scientific. Data processing applications are now covering a wide range, from standard payroll procedures, complicated in England by the use of pounds, shillings, and pence, to the mixing of ingredients using linear programming techniques, production control, and utility billing. Local governments are using computers for records and property-tax assessments.

British designers and manufacturers, and particularly potential computer users, are strongly conservative and set a high store on reliability (the users demand satisfactory completion of very exacting tests before accepting delivery).

In the smaller companies, the necessity for economy has meant a very careful investigation into the possible uses of computers, and reports that have crossed the Atlantic of unsuccessful installations have increased the timidity with which the subject is approached.

The increasing interest by both individuals and companies in electronic data processing is shown by the growth of the British Computer Society, started as the London Computer Group and expanded in the last 12 months to most cities in Great Britain.

The Large-scale Computer in England

The U.S. began building its first major computer, the ENIAC, while the war was still in progress, and since then defense contracts have supported digital computer development on a big scale. In contrast, British effort began during the two years following

TABLE I
MACHINES ACTUALLY INSTALLED IN GREAT BRITAIN

Year	Scientific design and research	Data processing
1949	1	—
1950	1	—
1951	4	—
1952	6	—
1953	8	1
1954	9	1
1955	18	2
1956	31	5
1957	56	25
1958	(86)	(67)

the end of the war, in the Universities of Manchester, Cambridge and London, and at the National Physical Laboratory of the Government Dept. of Scientific & Industrial Research. Shortly after these projects started, various British electrical manufacturers became associated with them. Financial assistance and encouragement were given by the National Research Development Corp., a body set up by Act of Parliament but not as a department of the government. The initiation of prototypes by commercial firms like Elliott Brothers (London), Ltd., Ferranti, Ltd., and EMI Electronics, Ltd., was among its contributions.

The design and the development of digital computers specifically for data processing has until recently been concentrated with the punched card manufacturers and with Leo Computers, Ltd. The latter company sprang from J. Lyons & Co., Ltd., food manufacturer and caterer, which had the foresight to see that electronic computers would be of great assistance in clerical operations. Not being satisfied with any of the machines available from either the U.S. or U.K., Lyons pioneered the first British data processing computer in collaboration with Cambridge University in 1949. This machine was developed for Lyons itself, but proved so successful that the company set up the manufacturing unit referred to above. The first model, developed from the Cambridge EDSAC, was in operation in 1953; the present computer retains much of the original logic and technology. Its stores consist of mercury delay lines which are now backed with magnetic drum and magnetic tape storage.

The National Physical Laboratory started design work on a machine known as ACE in 1947 and asked the English Electric Co., Ltd. to assist in the manufacture of the basic hardware. The engineering design work was extended so that a small operating machine, the Pilot ACE, could be manufactured. Magnetic drum storage had become available by then and in 1953 the specifications were completed for a fully engineered computer known as DEUCE. At that time it was agreed that only three machines should be made, one for the National Physical Laboratory, one for the Royal Aircraft Establishment, and one for the English Electric Co., Ltd. However, the demand for similar machines was such that without any commercial sales effort, three more machines were ordered in 1954/5 and in April 1955 the first machine was actually commissioned. To-date, the company has installed 20 of these machines for research and scientific work. DEUCE recently was fitted with magnetic tape equipment manufactured by the Decca Co.

While these developments were taking place, Ferranti, Ltd., was working with Manchester University, where the cathode-ray tube storage device was born, on research into the basic features of electronic computers. From this work, the Ferranti Mark I machine emerged for use at the university. PEGASUS was developed at the same time as a multipurpose data processing machine, Figure 1. The keynote of PEGASUS was packaged construction and good logical design using standard plug-in units and nickel delay lines as immediate access storage. The original PEGASUS was fitted with punched paper tape input and output mechanisms; those since then are designed for ElectroData-designed tape decks and IBM and British Tabulating Machine Co. punched card equipment. The company has extended its activities into the data processing field with a system known as PERSEUS and in the scientific field with a large computing installation known as MERCURY. It has also produced a magnetic tape off-line printing system using the ElectroData tape deck and a high-speed printer.

Elliott Brothers (London), Ltd. has developed a series of scientific and data processing machines known as the 400 series. The Elliott 405, now marketed by the National Cash Register Co., Ltd., was the first data processor to use British-designed 32-mm sprocketed magnetic film equipment. Elliott was also the first company in the United Kingdom to develop magnetic discs (capacity of 16,000 words). The 405 system was developed on a unit construction principle to allow the user to add to the basic computer. An Elliott card reader operating at 400 cards per min is now being fitted to computers made by other manufacturers.

A comparative newcomer to the field is EMI Electronics, Ltd., with its EMIDEC computer. This transistorized machine is fitted with 1,024 words of immediate access magnetic core storage backed by (up to) four magnetic drums of 16,384 words capacity each. EMI magnetic tape decks with a digit rate of 20,000 per sec will replace the Ampex tape units now in use. The EMIDEC has a two-address code, and in operations where two source addresses must be specified, one is also used as the destination. Transfers and arithmetic operations can take place

Fig. 1. Ferranti, Ltd.'s PEGASUS, designed for multipurpose data processing, uses plug-in construction, has magnetostriction delay lines for fast-access storage.

FIG. 2. A typical Mullard magnetic memory store. This unit contains 40 planes, each having 1,024 rectangular-loop Ferrox cores. Each core is threaded by four wires: an X-drive wire, a Y-drive wire, a digit wire, and an output wire. The total storage capacity of the unit is 40,960 digits.

between any of the 1,024-word registers, and the contents of any one of eight modification registers can be added to any instruction before it is executed. The control unit, in which the detailed operations to be performed for each instruction are obtained by the lacing of a magnetic core matrix, is such that if a customer wants to incorporate a specific function in his operation code it can be fitted easily at a reasonable cost. These facilities make the machine extremely flexible and suitable for both scientific and data processing work. Like most other British computers, the machine operates in straight binary.

File processing from 112 inputs

In addition to producing the EMIDEC, EMI has been working under contract from the National Research Development Corp. on a data processing system of the future. The center of this system is a computer using transistors as the logical elements with 4,096 words of magnetic core storage, which can be extended by further blocks of 4,000 words. The high speed is increased by the use of 64 diode-capacity working registers. Buffers can be switched by the program to any one of a number of magnetic tape decks. Primarily designed for use with off-line peripheral tape preparation and editing equipment, the computer works on a variable-word-length system, the addressing and organizing of which will be simplified by an automatic method of coding to make all words appear to the programmer as single-length one-brick words (one brick is a storage address and a word is made of a number of bricks required for a specific combination of digits). The off-line equipment for the preparation of input tapes is known as a multiplexing unit and has been designed specifically for keyboard input. A total of 112 electric typewriters are coupled to the multiplexing unit, the input from each collected line by line in a core store and sent with an appropriate reference to a 1-in. magnetic tape. This tape requires editing by the computer but provides a relatively cheap method of tape preparation. A file-and-search unit has also been designed for the bulk storage of records on multitrack 4-in. magnetic tape.

Once it is electrically switched to any one of a number of 4-in. tape-files, the search unit can select a record or sections of a record from the file. The input to the system is a 1-in. call tape giving an ordered list of record numbers and part of the record to be selected. The output is a second 1-in. tape containing the selected data and a notification of any errors occurring during the selection process. The 4-in. tape is run continuously, and editing and selection from the call-tape are carried out during the transfer process. The central computing unit can read from and write on to both the 1-in. and 4-in. tapes. The high speed of this machine suits it for both scientific and data processing applications, and although comparatively expensive, it should be highly profitable in terms of users' time. An off-line printing system operated by magnetic tape is also under development.

IBM (United Kingdom), Ltd., has sold a number of IBM 650 computers and one 704 computer in Great Britain. Production of 650's has begun in Greenock and delivery has already started. Although IBM is a comparative newcomer to the punched card field in England, it is already making its presence felt in this growing market.

Medium- and Small-scale Computers

Powers Samas Accounting Machines, Ltd., British Tabulating Machine Co., Ltd., Metropolitan Vickers, Ltd., and Standard Telephones & Cables, Ltd., have all developed small machines. (Two of these companies, British Tabulating Machine and Powers Samas, have combined to form a new company which should start operating in 1959, with the British Tabulating Machine Co., Ltd., as the majority shareholder.) The Powers Samas PCC has a limited storage of 160 words and is programmed by means of prepunched and eyeletted boards, which give the required programming instructions and are available for immediate access throughout the computing run.

British Tabulating Machine developed the HEC 2, a scientific machine, and the HEC 4, now known as the type 1201. The HEC 4 has 1,024 words of magnetic drum storage and two one-word quick access stores. Its arithmetic unit consists of four shift registers, an adder, and a complementer. This machine has proved extremely popular, mainly as an extension to an existing Hollerith punched-card system. The type 1201 was followed by the type 1202, which for the most part is a development of the former machine. The main changes are in the

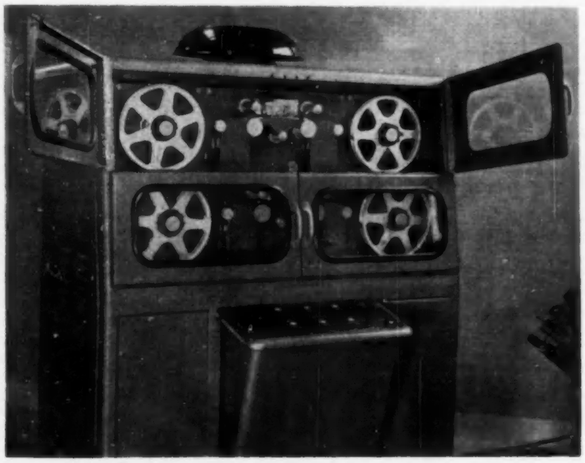


FIG. 3. The Decca twin-tape unit can transfer data at 80,000 bits per sec, holding up to 23 million bits on each tape.

provision of a larger drum (with 4,096 words of storage), an additional quick access store, and the ability to add into two registers instead of one. The company has also developed the type 1400, coming in 1961, which will be marketed initially with an arithmetic unit, a program controller, 100 words of immediate access core storage, a magnetic drum main storage, a console, and input and output buffers. This computer will be water cooled to reduce the air-conditioning required. Ultimate developments will increase the high-speed storage to a maximum of 1,000 words and up to four additional magnetic drums. Magnetic tape, printing, and punch-checking facilities will also be incorporated.

In 1956 the Metropolitan Vickers Co., Ltd., developed the Metro-Vick 950 computer with the object of providing a cheap, relatively fast machine with paper tape input and output for scientific purposes. This company is also manufacturing a data-processing system, known as the 1010, whose facilities include 2,048 or 4,096 44-digit words of magnetic core storage with an access time of 3½ microsec and a cycle time of 10 microsec. Auxiliary storage may be provided by magnetic drums of 8,192 words or by a 30-in. diameter drum with a capacity of 60,000 words. Decca twin-tape units, Figure 3, are used for magnetic-tape reading and writing, and all inputs, outputs and auxiliary storage are buffered.

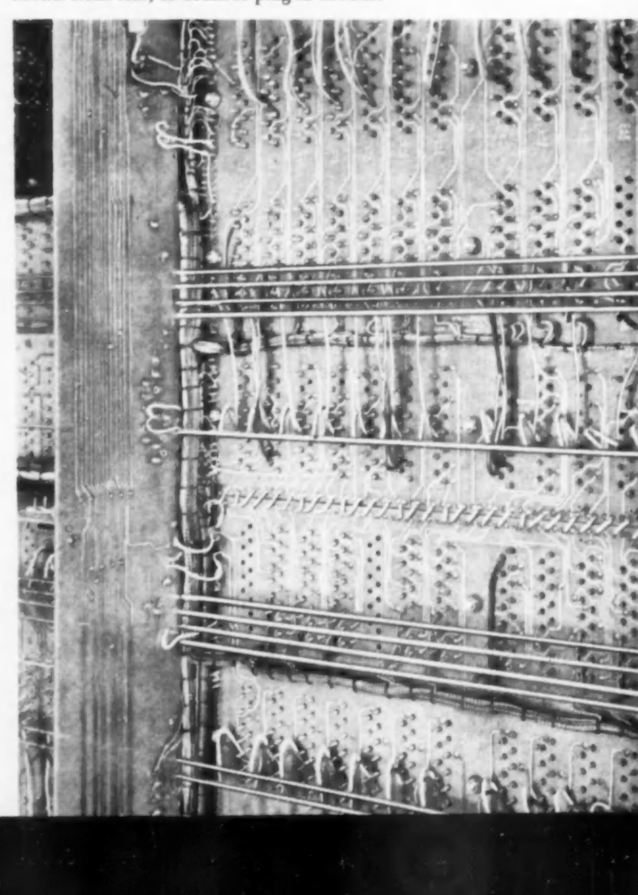
Any two or more programs can be operated concurrently if they have been written in accordance with certain conventions; but each program must have its own specific auxiliary apparatus under control and the total requirements for working storage of the program in operation must not exceed the capacity of the working store. Access to subroutines held in the drum stores may be shared. Facilities are also provided for temporary interruptions of one program in order to execute another of higher priority. Such interruptions may be complete or may be partial to allow parallel operation of both programs. The design uses transistors and printed circuits to insure reliability.

Printed wiring for automatic production

The STANTEC ZEBRA computer manufactured by Standard Telephones & Cables, Ltd., has unique instruction-word and logic facilities: instead of being decoded themselves, the instructions set up the necessary circuitry and more than one function may be carried out at a time by a single word. One of the cheapest computers available to the British market, it was designed from its inception with a view to large-scale production. The majority of its units are constructed from preprinted circuit panels into which plug-in units are fitted, see Figure 4. The design has been carefully worked out so that the minimum number of different plug-in units are used. Each unit has wrapped wire instead of soldered joints.

Equipment being prepared for the automatic manufacture and assembly of units for the Zebra and other electronic apparatus will use an insulated sheet, punched by a matrixing machine controlled by punched paper tape, to take the individual components. These will have their leads cropped and formed and be fed in sequence for insertion into the sheet. The formed ends will be looped over a herringbone strip of tinned brass and dipped in solders to make all connections at once.

FIG. 4. ZEBRA computer made by Standard Telephones & Cables, Ltd., uses printed wiring panels, shown from rear, to connect plug-in circuits.



The Zebra incorporates transistors in its track-switching circuits but in other respects uses electron tubes. A ferrite storage system has been developed for use as buffers between the Zebra and its magnetic tape equipment. Unlike the more usual magnetic core storage, in which each bit needs a separate doughnut of ferrite material, the ferrite core is a solid state device in which each bit stored is physically represented by a hole drilled through the block, as in Figure 5. The principle of operation is similar to that of the standard magnetic core store; i.e., both depend upon the squareness of the hysteresis loop of the material. At present, no outstanding claims are made about the advantages of the ferrite store, though advances in engineering techniques are disclosing the possibility of producing cheap quick-access storage. The holes in the block are drilled by means of ultrasonic techniques.

Tape Machines and Input-output Equipment

This group of companies has also produced two continuous-loop tape machines. The first, the Antwerp tape unit, consists of a loop of magnetic tape about 300 ft long, which is passed over a read-write head. Five or 10 such combinations of read-write heads and tape loops, each having its own associated reading and writing amplifiers, are incorporated into a single frame. The tape used is 1 in. wide with 12 tracks of 250 bits per in. and a speed of 100 in. per sec. The control of the tape feed is by a capstan with a suction couch. After passing over the read-write head, the tape is blown by air to the far end of the tape tank where it folds and settles under its own weight; it then moves toward the read-write head on a belt conveyor. The equipment provides a cheap and easy means of random-access storage.

The other machine uses a single-track quarter-inch magnetic tape; it was developed to replace the automatic punched paper tape handling device in the telegraphic communications field. This machine is capable of recording information received character by character on a start-stop basis and can hold over one hour's transmission on a single tape reel.

The input to the majority of British computers is a punched paper tape or card reader. Speed of reading paper tape has been increased to 1,000 characters per sec on five, six, seven or eight channels and the speed of reading of punched cards now is as high as 600 cards per min.

The most advanced example of input equipment is the direct character reading machine manufactured by the Solartron Electronics Group, Ltd., under the name of ERA. This device, which was described in CONTROL ENGINEERING in May (pp. 137 ff.), is capable of reading the printed information from tally rolls produced by cash registers or other devices.

Output equipment, as in the case of many medium and low-speed input devices, has been developed from existing telecommunications and punched-card equipment. In high-speed printing, the practice has been to import accessories, though British sources are now becoming available. One of these sources is the Samastronic printer developed by Powers Samas and now being fitted to a number of computers. It prints at a rate of 300 lines of 140 characters per min and uses a wire stylus for forming the characters.

Creed & Co., Ltd., is marketing two interesting items: a high-speed eight-channel paper-tape perforator capable of punching 300 characters per sec, with facilities to start and stop character by character, and a high-speed paper-tape printer operating at 100 characters per sec. Both are now being specified as part of the computing system of other manufacturers.

Despite the slower pace and progress of the British computer manufacturers, engineering standards are high and logical techniques sound. One of the most difficult phases of growing up, that of the first shock of transferring from the experimental to the production stage, is now passing.

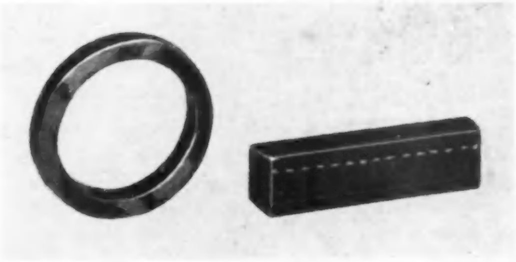


FIG. 5. Stantec's ZEBRA also uses drilled ferrite blocks like these in place of the usual cores for magnetic storage. The domino-like blocks allow for considerable simplification in construction of magnetic memories.

Incidentally, this development has taken place despite an acute shortage of men with the proper aptitude and experience in basic and auxiliary equipment design. This shortage is most marked in the use of solid-state elements and magnetic stores of kinds other than magnetic drums.

Neither transistors nor magnetic cores were available in quantity until comparatively recently, but the supply continues to improve. Research into the use of transistors is being undertaken by all the British computer laboratories but actual applications have so far been somewhat limited. The cost of transistors even in large quantities is not at present comparable to the cost of vacuum tubes in the United Kingdom and this fact, together with the limited supply available, has slowed the pace of development.

How to Design Wide-Band Constant-Phase-Shift Networks

Here's a circuit that maintains constant phase and constant amplitude over a fairly wide frequency range. The author used it as part of a speed-control system for three-phase synchronous motors. The circuit values developed for illustration produce a relative phase shift of 90 deg plus or minus 5 deg from 150 cps to 510 cps. Other amounts of phase shift are also possible over a frequency range which depends on the total phase deviation permissible.

RICHARD WHITE
Hoffman Electronics Corp.

Figure 1 is the block diagram of a single-phase to three-phase converter used to drive a three-phase synchronous motor from a continuously variable 150-to-500-cps single-phase source. The only problem is how to get a uniform 90-deg phase shift throughout the desired frequency range while maintaining constant two-phase amplitude.

The phase-shift circuit developed to do this is shown in Figure 2. Figure 3 is its circle diagram, which shows that the voltages E_{bd} and E_{be} must be equal and constant in amplitude for all frequencies with a constant input amplitude, E_{ac}. This satisfies one requirement of the network.

Consider the phase relationship of these two voltages to the reference E_{ac} and to each other. The

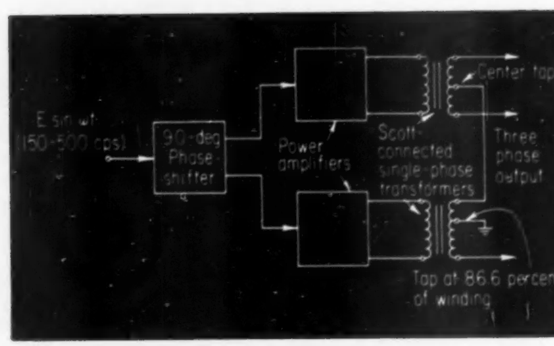


FIG. 1. Variable-frequency single-phase to three-phase converter that requires constant phase-shift network.

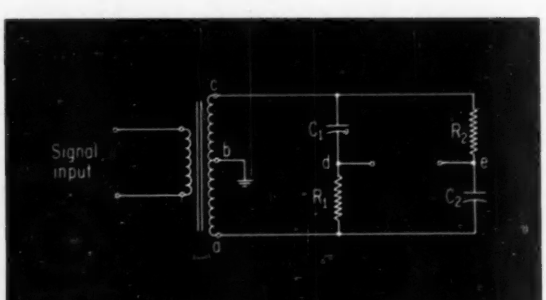
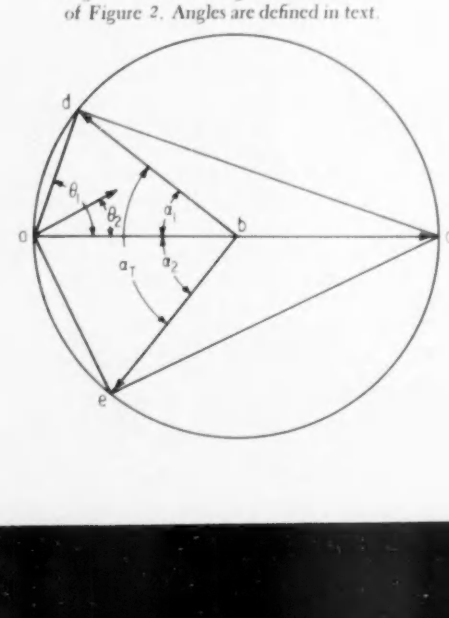


FIG. 2. This circuit can be designed to have relatively constant phase angle between points d and e over a fairly wide frequency range.

Fig. 3. Circle diagram for circuit of Figure 2. Angles are defined in text.



phase-shift angles of E_{bd} and E_{be} are α_1 and α_2, respectively. The angle between E_{bd} and E_{be} is then

$$\alpha_T = \alpha_1 + \alpha_2 \tag{1}$$

and the phase-shift angle equations are:

$$\alpha_1 = 180\text{ deg} - 2\theta_1 \tag{2}$$
$$\alpha_2 = 2\theta_2 \tag{3}$$

where θ_1 and θ_2 are the phase angles of R_1C_1 and R_2C_2, respectively. Expressed as functions of the components, these angles are:

$$\theta_1 = \tan^{-1}\frac{1}{\omega R_1C_1} \tag{4}$$

and

$$\theta_2 = \tan^{-1}\frac{1}{\omega R_2C_2} \tag{5}$$

Substituting Equations 4 and 5 in Equations 2 and 3 gives:

$$\alpha_1 = 180\text{ deg} - 2\tan^{-1}\frac{1}{\omega R_1C_1} \tag{6}$$

and

$$\alpha_2 = 2\tan^{-1}\frac{1}{\omega R_2C_2} \tag{7}$$

so that, by substituting Equations 6 and 7 in Equation 1:

$$\alpha_T = 2\tan^{-1}\frac{1}{\omega R_2C_2} - 2\tan^{-1}\frac{1}{\omega R_1C_1} + 180\text{ deg} \tag{8}$$

or

$$\frac{\alpha_T}{2} = \tan^{-1}\frac{1}{\omega R_2C_2} - \tan^{-1}\frac{1}{\omega R_1C_1} + 90\text{ deg} \tag{9}$$

Solving Equation 9 for $\tan \alpha_T/2$, yields:

$$\tan\frac{\alpha_T}{2} = \frac{\omega R_1C_1 - \omega R_2C_2}{\omega^2 R_1R_2C_1C_2 + 1} \tag{10}$$

and if $\omega R_2C_2 = X$,

and

$$\frac{R_1C_1}{R_2C_2} = K,$$

Equation 10 reduces to:

$$\tan\frac{\alpha_T}{2} = \frac{X(1-K)}{KX^2+1} \tag{11}$$

The ratio of the time constants, K, can now be calculated if the allowable deviation in phase shift is specified.

Solving Equation 11 as a quadratic in X and equating the two solutions to obtain a singular value for K, for a given maximum value of $\alpha_T/2$,

$$\sqrt{K} = -\tan\frac{\alpha_T}{2} \pm \sqrt{\tan^2\frac{\alpha_T}{2} + 1} \tag{12}$$

For a specified phase shift of 90 deg plus or minus 5 deg, the upper limit of $\alpha_T/2$ would be 47.5 deg. Substituting this in Equation 12 and solving for K yields a value of K of 0.15. Figure 4 is a plot of Equation 11 for K = 0.15.

Equation 11 can now be solved using the lower limit of $\alpha_T/2$, (42.5 deg). This gives the values of X corresponding to the upper and lower limits of the frequency range that can be covered. These abscissa values are 1.4 and 4.8. Solving for R_2C_2,

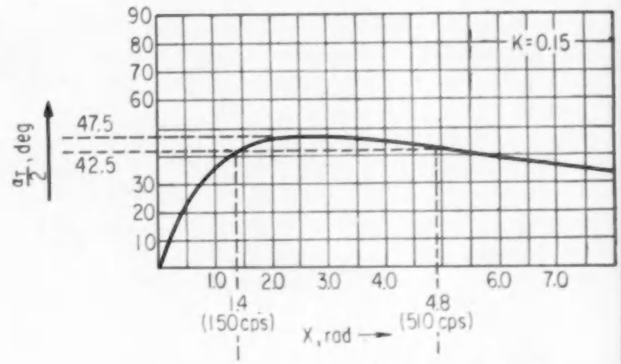


FIG. 4. Plot of phase shift vs. a function of frequency for the circuit of Figure 2 for a particular ratio of the two time constants.

$$X = \omega R_2C_2 = 1.4 \text{ at } 150\text{ cps}$$
$$R_2C_2 = 1.5 \times 10^{-3}\text{ sec}$$

and

$$R_1C_1 = KR_2C_2 = 0.22 \times 10^{-3}\text{ sec}$$

Checking the upper frequency,

$$X = \omega R_2C_2 = 4.8$$
$$f = 510\text{ cps}$$

The actual component values selected to give the required time constants were:

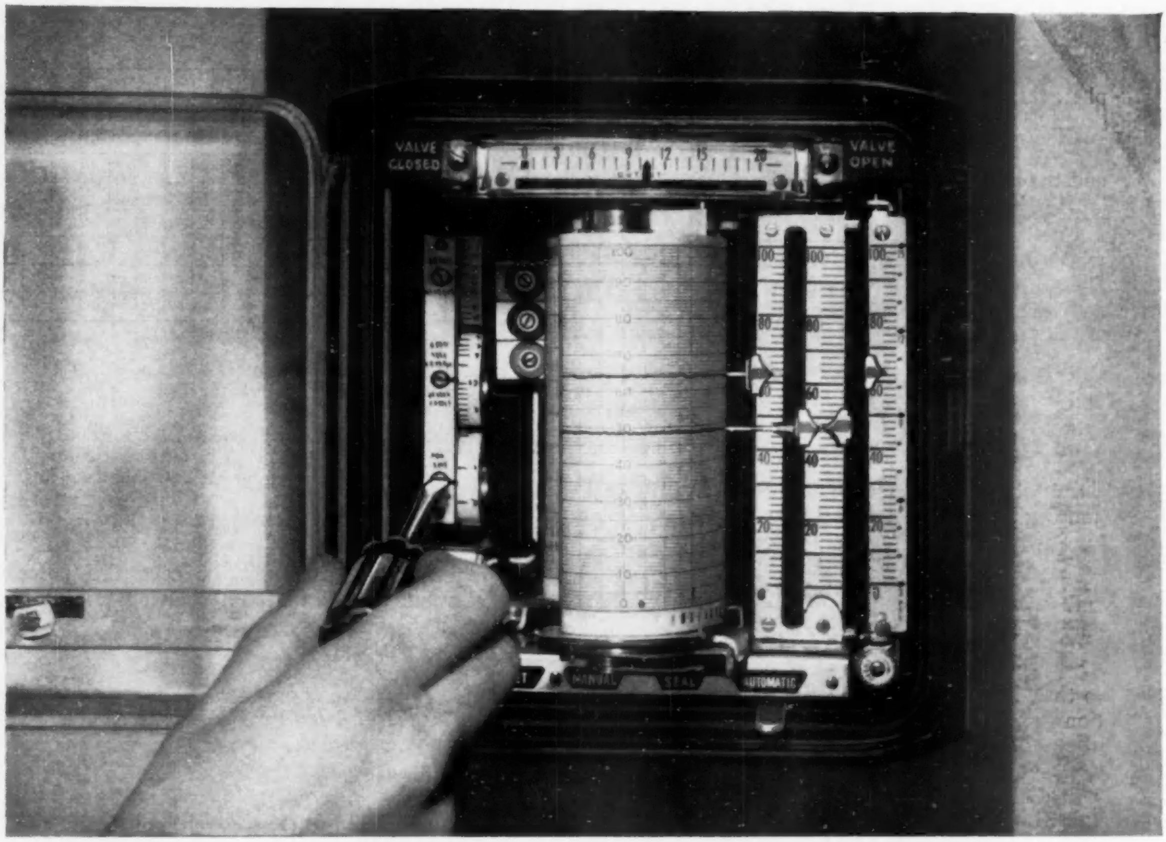
$$R_1 = 220\text{ kohms}$$
$$R_2 = 150\text{ kohms}$$
$$C_1 = 0.001\text{ mfd}$$
$$C_2 = 0.01\text{ mfd}$$

The circuit, constructed as shown in Figure 2, was checked in the laboratory with an audio oscillator and phase meter. The measurements made are tabulated in Figure 5.

The circuit described was developed while the author was employed by the George W. Borg Corp., and is used in equipment produced by Borg.

Frequency, cps	Phase angle, deg
150	87
200	93
250	95
300	95
350	93
400	90
450	88
500	85

FIG. 5. Measured values of phase angle at frequencies shown for circuit with component values developed in text.



WHY USERS ARE STANDARDIZING ON THE TAYLOR TRANSCOPE* RECORDER

Never before so many features in so little panel space!

1 All settings and adjustments made from front. Results are immediately obvious and the record is uninterrupted. Control response adjustments —when a TRANSCOPE Controller is mounted on the rear of the recorder—can be made with a screwdriver *without going behind the panel board.* Gain, reset and PRE-ACT* dials are calibrated in specific units.

This elimination of 'blind adjustments' is typical of the attention to detail that has gone into the design of the 90J series Recorders.

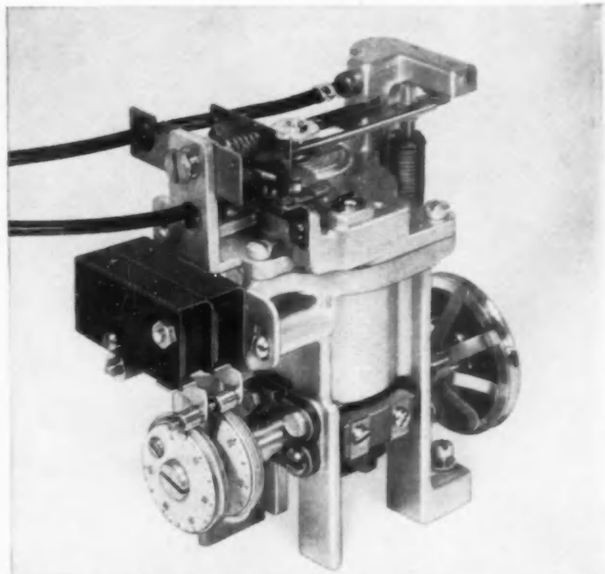
Also color-coded, adjustable signal-dampers (one for each recorded variable) are easy to get at, located right behind the chart drive.

2 Plug-in design. All principal assemblies are plug-in mounted for flexibility and easy accessibility. Individual unit parts are interchangeable.

3 Left-to-right record. 4″ rectilinear strip chart travels from right to left for easy reading. Gives continuous 30 day record (optional 24 hr.)—3 hour visibility. Most dependable chart drive ever devised—available in electric or pneumatic form. Pneumatic impulse twice as smooth as in conventional impulse drives.

4 Bumpless Automatic-to-Manual switching. Air leakage while switching is eliminated by an ingenious "O" ring slide valve. Selector lever travel is limited by mechanical stops, insuring positive positioning.

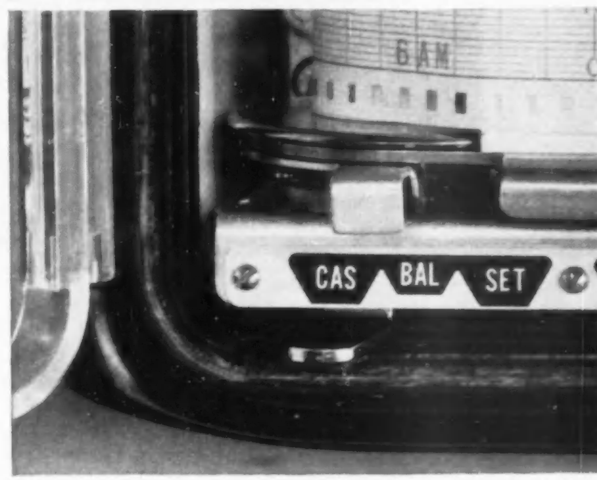
5 More accurate records. The Servomatic ▶ Motors give precise pen positioning. Essentially a power piston with a built-in positioner, the servomatic motor is the heart of the TRANSCOPE Recorder. Delivers 150 times more power than the conventional bellows type actuation, insure lifetime accuracy and sensitivity, a minimum of maintenance. *Servos are sensitive to changes of less than 0.1% in the pneumatic signal.*



6 Process Alarms provide built-in protection. ▶ As many as six process alarms can be incorporated in one recorder housing. Attached to the servo drive shaft, they may be either electric or pneumatic. Alarms are available in various combinations and may be set for high level, low level or band.

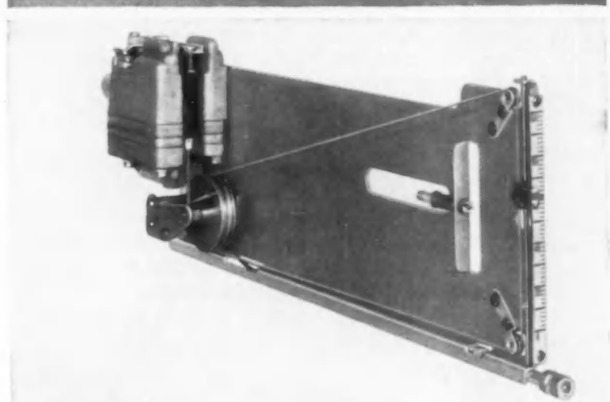
7 A Complete Cascade System in one case. ▶ The 90J Recorder was the first to incorporate a complete cascade system in one recorder case in a 6″ panel cut-out. It provides the simplest, smoothest process start-up. There are no external switches or relays. (Note unique Cascade-Balance-Set Switch.) Master and secondary variables are continuously recorded. Master and secondary controller outputs, as well as set points, are continuously indicated.

This outstanding feature of the 90J Recorder means substantial savings in instrument costs, panel space, operator's time.



8 Unique Set Point Transmitter allows continuous control. ▶ The 90J Recorder's Set Point Transmitter is a complete plug-in unit, separate from the main recording mechanism. Thus when the recorder slide is removed for checking the transmitter remains plugged into housing, keeping the process on uninterrupted, fully automatic control.

Thanks to this exclusive TRANSCOPE feature there's no need for process down time for instrument inspection or servicing.



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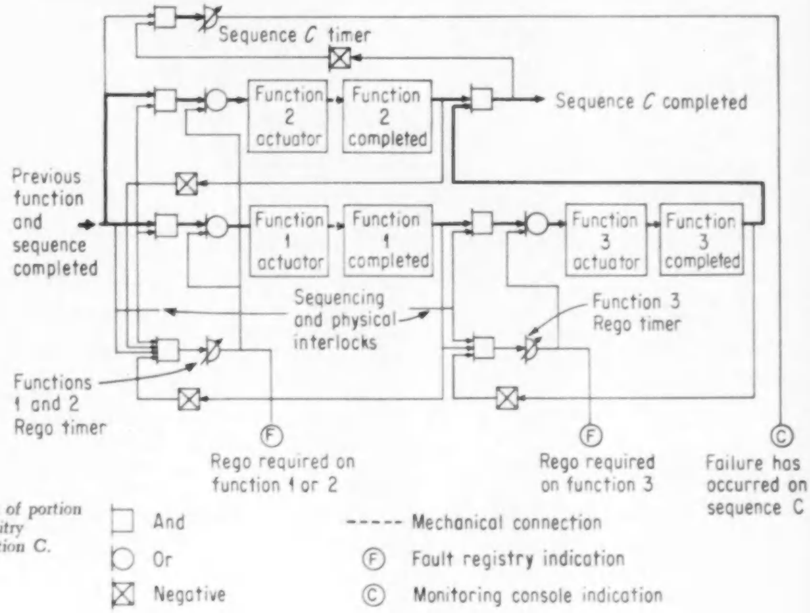
Taylor Instruments **MEAN ACCURACY FIRST**

Programmer Performs Quick-Fix On Own Failures

A recently tested missile-launching controller has built-in logic circuits that detect and indicate faults in its own operation, then make a temporary repair by substituting an alternate operational path automatically. The logical design of a typical portion of this controller is described here.



Logical operation of portion of quick-fix circuitry controlling Function C.

LAWRENCE KLEIGER
American Machine & Foundry Co.

An electronic "quick-fix" circuit, called "Rego", was included in the electrical controls designed for a recently tested automated missile-launching system. This circuit detects, locates, and indicates a fault, then automatically provides an alternate path to correct or by-pass a failure. A fault in a control system occurs when a function (1) fails to start on time, (2) fails to complete on time, or (3) proceeds out of sequence.

The complex control circuitry for the missile-launching system demanded a full complement of fault circuitry but a minimum of skilled personnel. For this reason, the first two of the three types of failures were combined into one common circuit. The logical operation is shown in the block diagram. Receipt of an indication that the previous sequence has been completed starts a new sequence, C, consisting of a number of functions. As each function is concluded, the next is initiated until all functions in the sequence have been completed.

Two timing devices, a function Rego timer and a sequence timer, are energized when the sequence is initiated. The function timer is set to time out shortly after the function is scheduled to be completed. If the function is completed within time allowances, the timer will be reset and no fault will be indicated. If the function is not completed, the timer times out and energizes the function actuator through another path, separate from the usual circuit. In addition, the fault is registered on a special fault panel, F. A delay in the completion of a sequence, caused by a sticky valve or worn bearing, could cause a fault indication. This information has value as a warning that a serious fault may occur soon. Maintenance then can be performed in time.

Parallel functions, such as Functions 1 and 2, are timed by the same function Rego timer. The fault display can be designed to register each fault separately, and thus remove any ambiguity, but this was not found necessary in the programmer illustrated. All groups of functions in series with each other and functions with greatly varying timers have separate Rego timing devices, such as the one used for Function 3.

The sequence timer is energized at the beginning of a sequence. It is set to expire after the usual time has elapsed for completion of all functions in a sequence plus a time allowance for "Rego". If the sequence has not been completed within this time, an alarm sounds and a fault is registered on the monitoring console, C. When such a fault occurs, further automatic functions are impossible; after examining the display console, the operator must determine what manual action is required.

As long as the automatic equipment can repair itself, the operator neither has to monitor the activity nor make decisions. The portions of the automatic circuitry that failed will be registered on the fault panel and repaired at a later time.

It is also possible to record the number of operations of a component and replace it when it enters the unreliable portion of its life.

 CIRCLE 56 ON READER-SERVICE CARD

Measuring Phase of Distorted Signals

BENJAMIN BARRON, *Magnetic Amplifiers, Inc.*

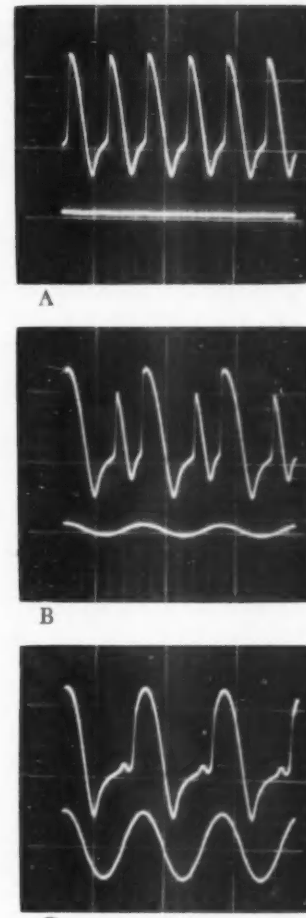


FIG. 1. Input and output waveforms from half-wave magnetic amplifier. Effective output voltages shown (upper waveforms) are: A—0 volts; B—36 volts at plus 20 deg; C—62 volts at plus 10 deg.

The idea of "relative phase" ceases to have meaning if two ac signals are dissimilar; and the problem of measuring this phase shift gets quite difficult, particularly if the signals may be asymmetrical about zero amplitude. The control engineer meets this problem often; e.g., when he tries to measure the relative phases of the voltages on the windings of two-phase ac servomotors in magnetic amplifier or thyratron circuits. Some means of measuring the "effective relative phase shift" is needed in such cases.

Magnetic amplifiers and thyratrons produce large amounts of waveform distortion. Figure 1 shows typical output waveforms from a half-wave magnetic amplifier for a sinusoidal input signal. Notice that the output is very large, even for zero input. Motor torque in such circuits is produced by the algebraic difference in average voltage between successive half-waves, as well as by their phase with respect to the servomotor reference phase.

It is common practice to produce a servomotor's reference phase voltage by shifting the servoamplifier's carrier input through 90 deg. But there is some phase shift through any magnetic amplifier, so that effective phase of the amplifier output will no longer be at 90 deg to the motor reference phase, and this technique will not produce maximum motor torque. A better technique is to measure motor torque with a spring scale while adjusting the phase shifting network. This procedure is awkward, however, and slow.

A phase analyzer has been developed which permits very simple, quick determinations of effective phase shift, regardless of waveform distortion. Figure 2 is a block diagram of the new phase analyzer. In operation, the synchronous switching demodulator inverts alternate half-cycles of the distorted amplifier output voltage at times determined by the positive-going zero point on the reference sine wave. The reference voltage for the phase analyzer must be the same phase used for the carrier input to the servoamplifier.

The effect of shifting the switching point of the demodulator is illustrated in Figure 3. The angle θ in Figure 3 is read directly as a lead or lag angle from a dial on the analyzer. The phase dial, easily adjusted to maximize the voltage reading on the rms-calibrated ac voltmeter, then reads the reference signal phase shift which will produce maximum torque. Figure 4 shows the waveform applied to the meter by the demodulator, with the meter reading maximized by shifting the reference sine wave, for a typical magnetic amplifier wave form.

The phase shift circuit, Figure 5, used in the phase analyzer is quite unusual. Potentiometers *R*1 and *R*2 are ganged together and *R*2 is center-tapped. The in-phase and quadrature vectors vary directly with the mechanical rotation of the potentiometers. Thus, at 0 deg the reference voltage vector is at *a-c* in Figure 5B; at 90 deg it is at *a-b*; and at 180 deg, at *a-d*. The end of this vector follows the equilateral triangle shown in Figure 5B. Since the potentiometers are

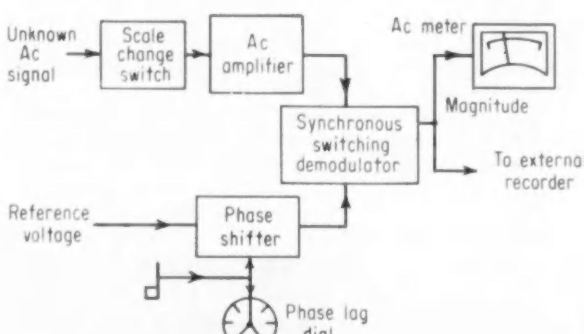


FIG. 2. New phase analyzer uses amplifier carrier input as phase reference signal. Phase dial is turned to get maximum reading on ac meter and effective phase angle is read directly from dial.

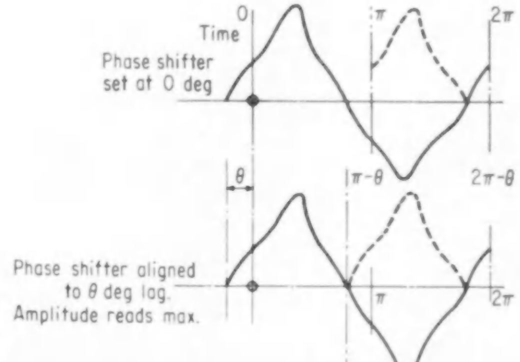
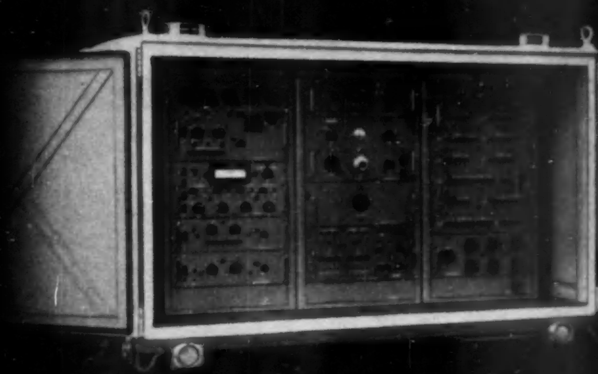


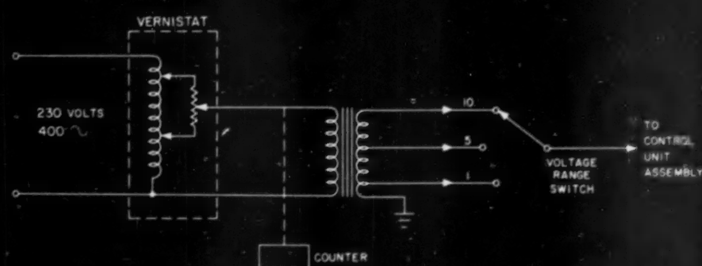
FIG. 3. Phase shift dial moves reference frame of switching demodulator, which inverts alternate half-cycles of input. Meter reads maximum when demodulator output is all positive or all negative.

Eclipse-Pioneer designs test set for B-58 Hustler autopilot system...



An automatic flight control system that "thinks ahead" of the pilot is a "must" for the Air Force's Convair B-58 Hustler — world's fastest bomber. "Brain" of this system — developed by Eclipse-Pioneer Division of Bendix Aviation Corporation — is a compact control unit assembly in which all flight factors are continuously and instantly translated into commands to control surfaces. To check out this assembly quickly and conveniently, a mobile test set has also been designed — and **Vernistat is there** as an accurate source of test voltages in simulating a number of signals and commands.

...and Vernistat* is there!



Vernistat a.c. potentiometers were selected for several of the test panels because of their unique combination — in one component — of reliability, low output impedance, low phase shift, and high linearity. In the typical application above, a Vernistat is mechanically geared to a counter to provide an output voltage that can be accurately set to the required value. Low phase shift from input to output is maintained by the Vernistat's inherent design. And need for an isolation amplifier — with its added cost and disadvantages — is eliminated.

Doesn't Vernistat thinking belong in your system design too?

In this application, Vernistat thinking by Eclipse-Pioneer engineers helped solve a design problem with reduced equipment cost, system complexity, and design time. Cost was only a quarter of that of an alternative method utilizing conventional potentiometer, isolation amplifier, and d.c. power. Use of fewer components reduced system complexity, increased accuracy and reliability, and saved valuable design engineering man-hours.

In servo systems, analog computers, and similar uses, you too can obtain such results with Vernistat a.c. potentiometers. With this new concept in relating shaft position to voltage, you get low output impedance (as low as 45 ohms) with high input impedance (as high as 200,000 ohms), plus high resolution (to 0.004%), low phase shift (as low as 0.2 minutes), and high linearity (to 0.01%).

In addition to precision a.c. potentiometers, Vernistat products include function generators (adjustable non-linear potentiometers), and variable ratio transformers. Military specifications are met by the wide selection of models available.

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 CIRCLE 57 ON READER-SERVICE CARD

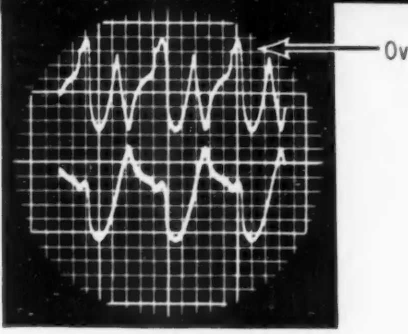
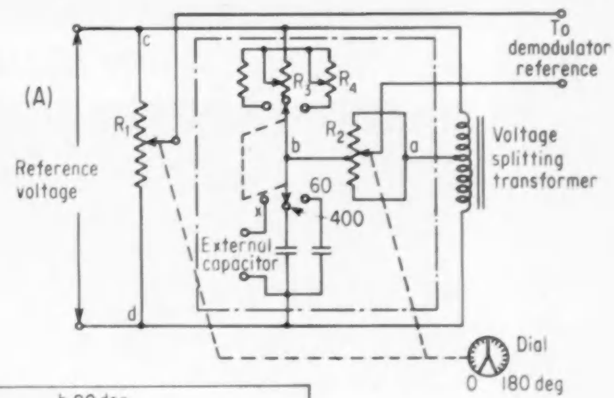


FIG. 4. Below—typical magnetic amplifier output waveform; above—same waveform as switched by demodulator with phase dial adjusted to give maximum meter reading. Small pips above zero line are due to incomplete reset in magnetic amplifier



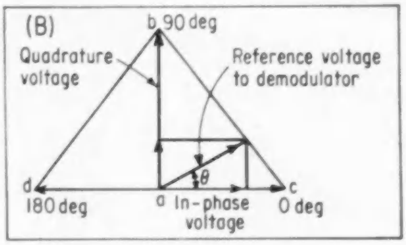


FIG. 5. A—phase shifting circuit used in analyzer; B—output of phase shifter follows triangle c-b-d.

linear, phase shift versus rotation is not linear; this nonlinearity is corrected during calibration of the phase-shift scale. Capacitors are provided in the analyzer for phase shifting 60- and 400-cycle voltages. A capacitor may be added for any other frequency.

Processing Data from the Open Hearth

R. H. BAULK
Samuel Fox & Co.,
Sheffield, England

As the first stage in a continuing research program at Samuel Fox & Co., Ltd., a digital data processing system built by United Steel Companies, Ltd. is collecting and analyzing data from the Fox Co.'s open hearth furnaces. The system takes only half an hour to produce the totals and means for six variables.

One aim of the program will be to correlate furnace roof life against the frequency and durations of the excursions of roof temperatures above operating ratings.

There are four phases in open hearth work–charging, melting, refining, and fettling. For each phase, six variables are recorded: oil flow, steam flow, air flow, furnace pressure, and roof temperatures at two points. Information on each variable is converted at the furnace control panel to a 0-30-ma signal (see figure) and fed to a channel selector stepping relay. The relay is driven from a 1-rpm motor that steps through 10 channels (four are spares) in 50 sec.

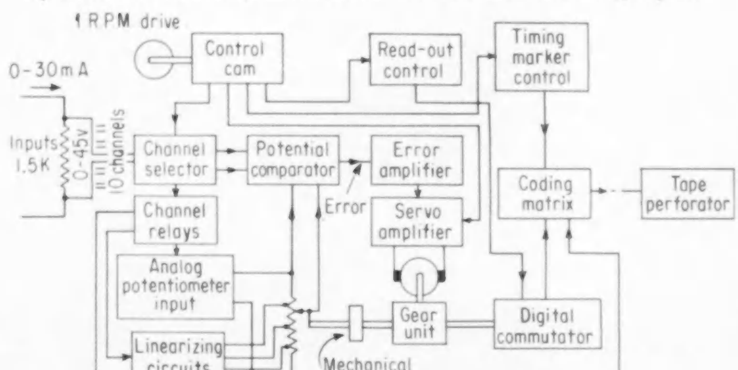
The information on each channel is compared against a constant voltage source in a self-balancing potentiometer. As each channel is energized, relays adjust the voltage source and linearizing circuits across the reference potentiometer. The potentiometer servomotor drives a binary-coded decimal commutator which encodes the analog voltage. A matrix translates this code to paper tape code prior to transmission.

The coded pulses are transmitted from the furnace control panel to a perforator in the instrument room that produces five-channel tape on which each variable has separate rows for its units, tens, and hundreds digits. A synchronous motor adds 1-min timing pulses to this tape. The furnace tapping signal comes from a photocell focused on the ladle. The four phase times are obtained from normal operational records and inserted manually.

When the cast is complete, the tape is run into an analyzer, developed by Elliott-Automation, which accepts up to 10 inputs, averaging them over a preset period or totalizing over the whole cast. In the averaging process, each variable is counted on neon tube counters until the number of timing pulses received from the tape corresponds to the preset phase time. The tape feed then stops and the analyzer divides the count by the number of inputs received. The results of the averaging together with the totals are then printed out for each variable.

When the printout is complete the analyzer automatically proceeds to the second, third, and fourth phases, averaging, totaling, and printing out the results. The tapping signal indicates that the cast is complete.

Open hearth data reduction system encodes furnace variables to standard Teletype signals.



SPEAKING WITH EASE.

Oven for computing resistors and capacitors receives up to twelve drawers of components. Engineer points to regulated outer oven that pre-heats connecting wires to temperature of precisely-stabilized inner chamber.

WHAT ANALOG COMPUTER USERS SHOULD KNOW ABOUT STATIC ACCURACY

How to Evaluate Static Accuracy

Static summing accuracy, being the foundation on which over-all computing precision rests, deserves careful analysis by computer users. A single figure like ".01% accuracy" has little meaning unless supplemented by less ambiguous statements. Fortunately, static error caused by modern high-gain, low-drift amplifiers is negligible; therefore, questions of static accuracy can be answered by discovering how well input and feedback resistors have been matched in order to produce resistance ratios of 1:1, 10:1, etc. The following questions are pertinent.

(1) Exactly *how* are resistors matched? Each with every other? Or each with a few others in a group?

(2) What is the matching error upon installation?

(3) How will environmental conditions such as temperature affect accuracy?

(4) Will accuracy deteriorate with age and use? If so, how much?

(5) Will resistors added to expand capacity at a later date match those initially installed?

Let us examine these questions in greater detail.

Two Methods of Matching Resistors

One method is to match resistors in groups of four or five—each to be used only in conjunction with one or more of the others, as input and feedback resistances for a certain amplifier. This method can provide sufficient accuracy, but computer capacity is unnecessarily limited because input resistors cannot be freely transferred from one amplifier to another as needed.

An alternative is to match each resistor with every other in the computer, so that every element will be available for use wherever needed. The EASE computer people have accomplished this by calibrating all computing resistors against a single master standard carefully maintained under laboratory conditions.

The master standard is a group of 100K resistors specially-selected to deviate from a central value less than ±2 PPM and guaranteed to differ no more than ±15 PPM from an absolute 100K value. 1M computing resistors are calibrated against the ten 100K resistors connected in series. 100K resistors are calibrated against the *average* of the ten 100K standards so that the 10:1 ratio is free from the possible 2 PPM deviation of the standards. 200K and 500K computing resistors are similarly calibrated against group averages to achieve exact 5:1 and 2:1 ratios respectively. Using these calibration practices, all computing resistors in an EASE 1100 Series computer are initially adjusted to *within 10 PPM* of the ideal value.

Effect of Temperature On Static Accuracy

No static accuracy figure is meaningful unless accompanied by a statement of the environmental temperature range over which specified accuracy can be achieved. Because EASE computing resistors are installed in an oven maintained within ±0.5° C of a constant temperature, resistance changes due to temperature are less than 15 PPM—this despite external temperature variation from 65° F to 110° F and line voltage changes from 105 to 130 volts.

Field tests have confirmed the effectiveness of this mode of calibration and temperature control. Figure 1 shows the distribution of 100K and 1M resistors in an operating computer. A fact worthy of emphasis is that measurements were made *at the patchboard* under actual operating conditions; consequently, all possible sources of error have been taken into account. With precision computing equipment, only tests made under operating conditions are dependable because so many unpredictable factors such as slight connector contact resistance, wiring resistance and possible human errors in calibration can influence the theoretical result. Note that *typical resistance deviation is about ± 20 PPM* and maximum deviation is 50 PPM except for 1 delinquent out of 1000 which has strayed to 60 PPM.

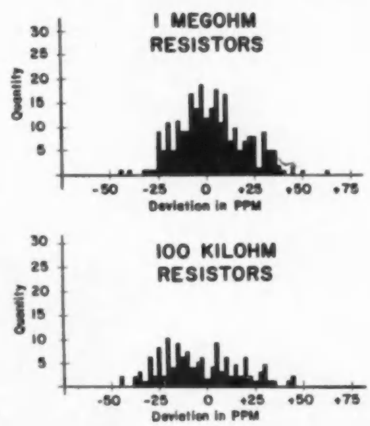


Figure 1. Distribution of all 100K and 1M resistors in 1100 Series computer used at EASE Los Angeles Computing Facility. All measurements made at the patchboard under actual operating conditions.

Aging Effects

The principal effect of age on resistors is to modify resistance values as heat stresses set up in manufacturing processes slowly decay. To forestall this effect EASE computing resistors are heat-cycled four times far above and far below operating temperature in order to remove heat stresses before calibration.

Although no EASE 1100 Series computing resistors have been in service long enough to make a definitive report an stability over a period of years, preliminary tests indicate very low drift. A group of computing resistors, kept at the EASE laboratory for long-term testing, show no greater individual deviation outside the original calibration tolerances than ±15 PPM over a period of six months.

Will Later Expansion Affect Accuracy?

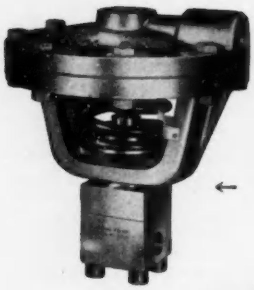
An analog computer user must give due weight to the possibility that an initial installation may require expansion at a later date as new problems are encountered and new solution techniques developed. At that time it becomes important to obtain new resistors matching those originally installed. Here also the use of a single master standard for calibration is advantageous. Provided the master standard has not drifted in value, new risistors can be calibrated to match those in the computer as well as the initial set.

Absolute drift of a few parts per million is difficult to detect with certainty, but all evidence indicates that the EASE standard has not drifted. None of ten basic resistance standards show detectable long-term drift over one year when compared with each other or when compared to other high-stability standards within the laboratory. Since it is extremely improbable that these standards have all drifted the same amount and in the same direction, we infer that the absolute value is holding steady.

Beckman® / **EASE COMPUTERS**

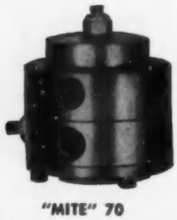
Mfd. by Berkeley Division, Beckman Instruments, Inc. Richmond 3, California

MINIATURIZATION From Pilot Plant to Process



"BANTAM" 500 SERIES VALVE

Throttling "Bantam" Diaphram Control Valves for all standard control valve uses, Cv of 0.6 and below, up to 1000 psi and 500°F, characterized, renewable trim, 316 stainless steel and Teflon only wetted surfaces, low in hysteresis size and weight, 2000 series "Bantam" Control Valves available for on-off service.



"MITE" 70

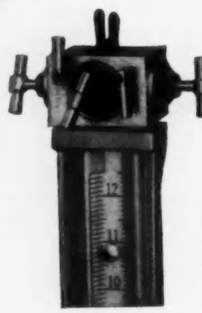
Pneumatic signal monitor. Embodies safety trip-out with manual or remote pneumatic reset. 250 PSI maximum pressure with trip adjustment for lock-up or vent from 1 to 100 PSI. Standard materials blue anodized aluminum. Other materials and models with integral two or three-way valves available.

"DEMI" PACKLESS VALVE

For services when packing is a problem, manifolding of small valves in one unit at low cost. For services up to 750 psi and 500°F, screw, toggle, or diaphragm operated, the "DEMI" line is ideal for panel mounting up to five valves in one block.

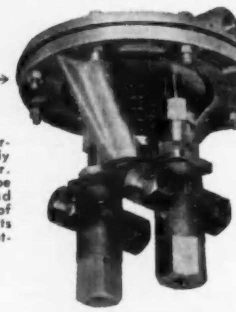
"DEMI 54"

5 Valve Manifold for integral mounting on cleanout type Manometer. Packless design, 2 shut off valves, one bypass valve, 2 vent valves. Other 3 or 5 valve models available with or without special manometer mounting.



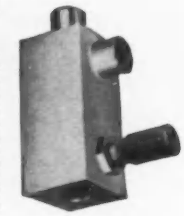
WHIFFLETREE OPERATOR

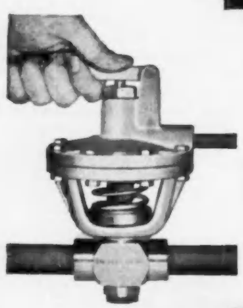
Two valves operated simultaneously by one operator. Valves may be globe or three-way and have a multitude of piping arrangements for mixing and routing applications.



CONSTANT VOLUME REGULATOR

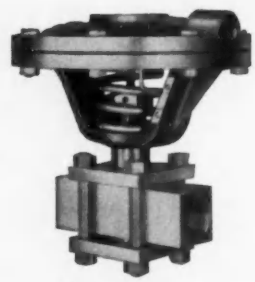
Fully automatic regulation provides constant volume output of gas or air regardless of fluctuating pressure drop. Capacity control by micrometer adjustment assures accuracy of desired output volume from 5.0 to 180 SCFH at pressure differentials from 1 to 25 PSI. Brass Body.





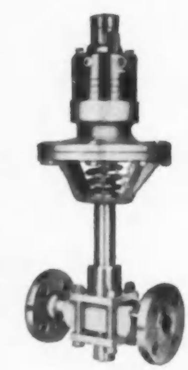
MANUAL RESET

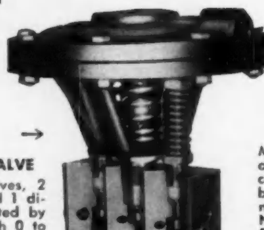
Wherever control air on dangerout or toxic process flows must be blocked for safety, on air failure until manually reset, these valves insure against disaster. Standard sizes ¼" and ½" I.P.S.



THROTTLING CONTROL VALVES WITH TOP MOUNTED MOORE POSITIONER

Compact, accurate and rugged. Light weight. Sizes from ¼" to 1" NPT. Flanged connections available. Barstock bolted bonnet, blindhead and body. Cv. from .001 to 10.0 with pressures to 1000 PSI.





BLOCK VENT VALVE

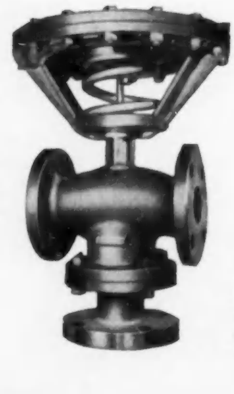
3 balanced valves, 2 reverse acting and 1 direct acting, actuated by one operator. With 0 to 3 psi control air, the 2 reverse acting valves are closed, center valve vented. At 6 psi control air, all valves closed. At 12 to 15 psi, the 2 reverse acting valves are open and the vent valve is closed, allowing free flow through body. Design pressure 1000 psi. Teflon, Chevron packing. Teflon seating for tight shut off.

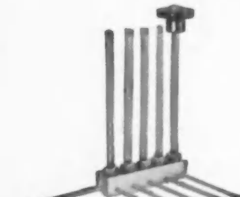
AIR OPERATED CONTROL VALVE

Miniature diaphragm operated control valve. Barstock construction with bolted bonnet and blindhead. Connections from ¼" to 1" NPT. Cv. from .001 to 10.0. Direct or reverse acting operators for control applications. Extension bonnets for extreme temperatures available.

DIAPHRAGM OPERATED 3-WAY CONTROL VALVE

Aluminum diaphragm operator, stainless steel body and trim, Teflon packing with Teflon seating for tight shut off. Available up to 2", flanged or screwed.





MINIMUM VOLUME MANIFOLD

A compact manifold consisting of five packless valves having .0006 cubic inches volumetric displacement. Can be cam actuated for programming applications. Soldered, welded, tubing or NPT connections with applicable materials of manufacture for high temperature and high pressure service.

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Write us for complete technical information, or for the address of our representative in your area.

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 CIRCLE 59 ON READER-SERVICE CARD

VICTOR DIGIT-MATIC PRINTERS

Proved by over 16,000,000 printings without repairing, adjusting or cleaning!

The adding machine in the Digit-Matic has been tested with over 16,000,000 continuous printings, with no failure, no service other than periodic oiling. Forty years of experience in producing 1,500,000 adding machines—as well as precision instruments such as the Norden Bombsight—has given Victor Adding Machine Co. outstanding qualifications for producing rugged and reliable digital printers.

CHECK THESE 4 VICTOR ADVANTAGES

Reliability: Examine the rugged construction of a Victor machine. Each part is conservatively designed to provide extended life and reliability. Wearing surfaces heat treated, cyanide hardened to stand up under constant use. All steel parts cadmium plated to prevent rusting.

Immediate Service: Factory-trained servicemen (and parts) are on call in more than 725 cities coast to coast.

Flexibility: At least 500,000 different combinations available, with speeds up to 33 characters per second. With Victor Digit-Matics you have your choice of listers, accumulators, or calculators *plus* an almost infinite number of other variations ranging from electrical noise filters to upside-down printing.

Fast Delivery, Low Price: Because of Victor's continuous high volume of adding machine production, we can ship almost any quantity of Digit-Matics—built specifically to your order—within 30 days. Victor Digit-Matics, from only $425.00, are the value buy in the digital printer field.

VICTOR SERIAL ENTRY DIGIT-MATIC PRINTER

10 Digit solenoids. Digits are entered in sequence with most significant digit first. Accepts digits at a rate up to 20 per second. Print cycle: listers 0.27 seconds; accumulators 0.35 seconds. Available in up to 11 column entry capacity.

COIL DATA

Voltage	21-28VDC	42-54VDC	125-160VDC
Resistance, ohms			
Digit solenoid	25.5	75.0	490.
+ or − Print solenoid	25.5	75.0	450.
Minimum on time, seconds	.02	.02	.02
Maximum on time, seconds (continuous printing)	.05	.05	.05

Minimum off time between digits—all serial entry machines—.025 seconds.

COVER REMOVED

VICTOR PARALLEL ENTRY DIGIT-MATIC PRINTER

All digits 1 through 9 of each column equipped with solenoids. Digit and print command solenoids may be simultaneously energized. Print cycle:—listers 0.30 seconds; accumulators 0.35 seconds. Available in up to 10 columns entry capacity.

COIL DATA

Voltage	20-28VDC	35-56VDC	125-160VDC	105-125VAC
Resistance, ohms				
Digit solenoid	17.6	53.0	700.	125.
+ Print solenoid	17.6	89.0	375.	125.
− Print solenoid	17.6	53.0	375.	125.
Minimum on time, seconds	.020	.020	.015	.025
Maximum on time, seconds (continuous printing)	.050	.050	.035	.050

A few popular model variations:—columnar spacing; right side of machine accumulating and left side listing data identification; Non-Add printing; Non-printing adding; MIL-I-17623 Electrical Motor Noise elimination; Induction Motors; Manual Keys over the solenoids; "digit key depressed" switch (serial entry Digit-Matics); tag and label printing; and all kinds of alphabetic and special types.

VICTOR

Write today! Victor's electronics-trained staff will gladly help you solve any digital printing or calculating problem.

Write for technical manual No. B11-71.

Electronics Division

VICTOR ADDING MACHINE CO.

3900 N. Rockwell Street, Chicago 18, Ill.

 CIRCLE 61 ON READER-SERVICE CARD

Newest

HONEYWELL MINIATURE RATE GYROS

Rugged enough to withstand 100 G shock

Typical M Series Gyro undergoes 20 G Linear Vibration Test with no deterioration of performance.

Model M-1
shown actual size

Sensitive enough to detect 0.005° per second

Honeywell's newest miniature rate gyros, Type M Series, are rugged enough to withstand repeated shocks and linear accelerations up to 100 G yet sensitive enough to detect turn rates of only 0.005 degrees per second. A damping ratio variation of 2 to 1 or better is maintained without heaters by a unique fluid damped, temperature compensated system that assures reliable operation over the entire operating temperature range.

Type M Series Gyros are specifically designed for autopilot damping, radar antenna stabilization and fire control applications. Their small size, high performance and ruggedness suit them particularly for high performance military aircraft and guided missile applications. Write for Bulletin M to Minneapolis-Honeywell, Boston Division, Dept. 34 40 Life Street, Boston 35, Mass.

DESCRIPTIVE DATA

FULL SCALE RANGE: to 400 degrees per second

THRESHOLD-RESOLUTION: 0.005 degrees per second

LINEARITY: 0.1 % to 2 % depending on range

DAMPING: 2 to 1 (or better)

TEMPERATURE RANGE: −65 to +200 and +250°F

SHOCK AND ACCELERATION: 100 G

VIBRATION: 20 G to 2000 cps

PICKOFF: Variable Reluctance type providing infinite resolution and high signal-to-noise ratio

MOTOR EXCITATION: 26 volts, 400 cps (standard) 2 phase and 3 phase

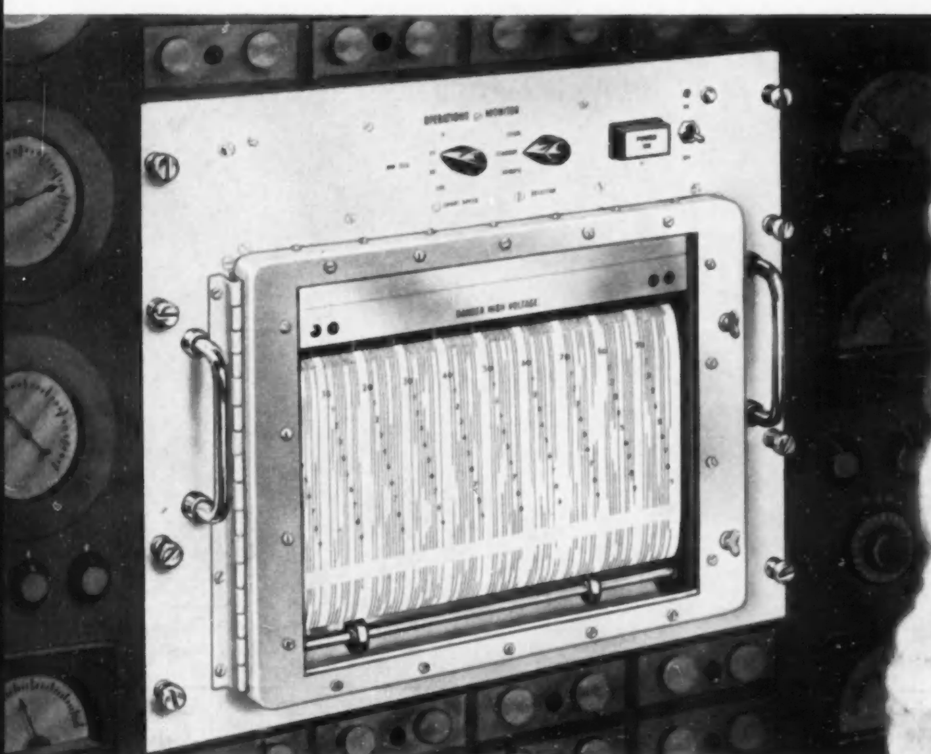
SIZE: 1" diameter, 2 ¾" long

WEIGHT: 4.5 ounces

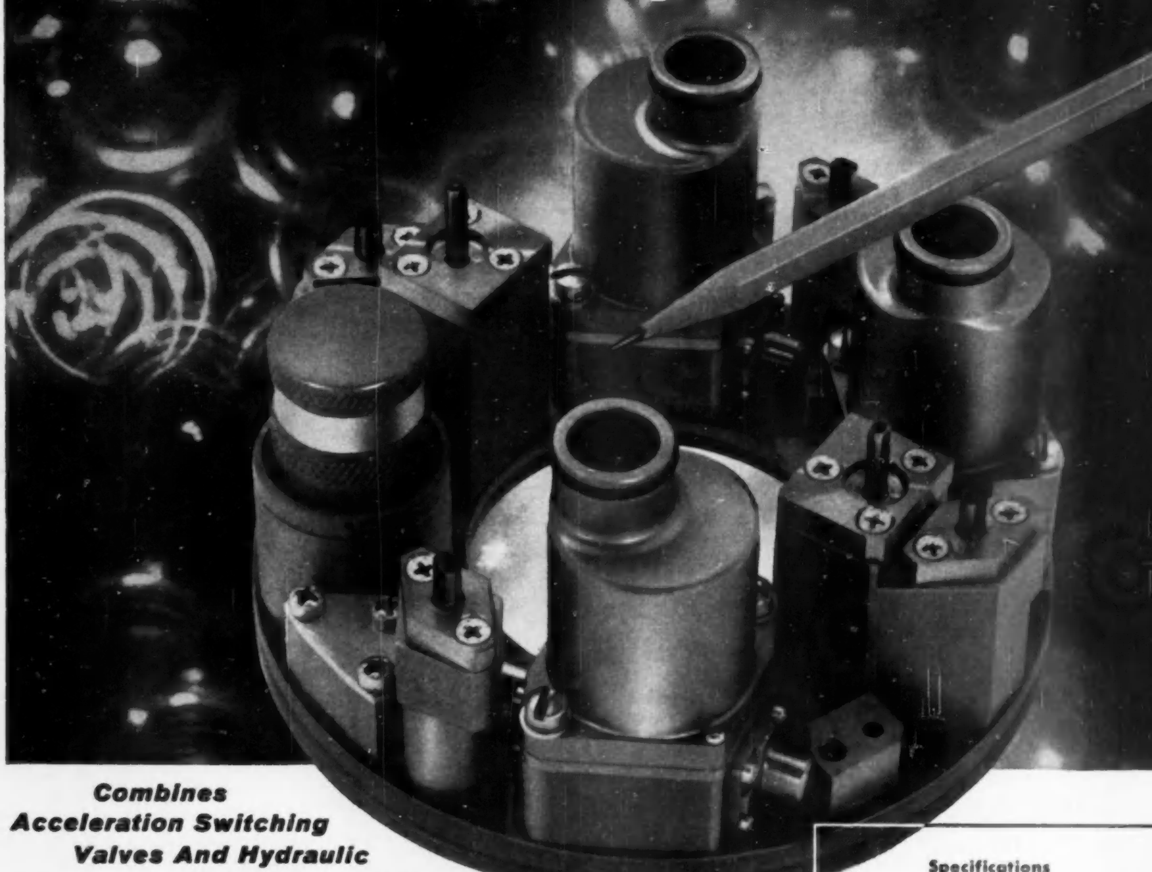
Honeywell

H *Military Products Group*

 CIRCLE 63 ON READER-SERVICE CARD CIRCLE 64 ON READER-SERVICE CARD→



NEW AiResearch steering control system



Combines Acceleration Switching Valves And Hydraulic "Printed Circuit"

More reliable and responsive... this lightweight electro-hydraulic steering control system converts low-level electronic signals from the main guidance system into hydraulic energy which actuates the mechanisms steering the missile.

Packaged as an integrated unit, the three servo valves and six control actuators are mounted on a common manifold and powered by fluid or hot gases. The simplified "printed circuit" system of integral passageways within the manifold eliminates all external plumbing and leakage.

The acceleration switching servo valves provide positive control of spool velocity, thereby achieving greater resolution, reliability and response even at extreme temperatures.

Easily installed and removed as a complete, interchangeable unit, acceptance testing of this compact system can be accomplished prior to missile installation. Suggested applications are: missile surface controls, jetavator controls, and vector and nozzle steering controls. Your inquiries are invited.

Specifications

Actuator load (range)	*90 to 150 in. lbs.*
Electrical input (nominal)	*28 volts DC—10 Milliamperes*
Pressure range	*500 to 3000 psi*
Rated flow	*½ to 2 gpm*
Mounting	*Manifold*
External leakage	*None*
Proof Pressure	*4500 psi*
Burst Pressure	*7500 psi*
Temperature operating range	
Fluid	*−65°F to 450°F*
Ambient	*−65°F to 750°F*
System filtration	*10 microns*

ENGINEERING REPRESENTATIVES: AIRSUPPLY AND AERO ENGINEERING, OFFICES IN MAJOR CITIES

THE GARRETT CORPORATION

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Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

IMPROVED SWITCHING CHARACTERISTICS!

DELCO HIGH POWER TRANSISTORS OFFER UNSURPASSED PERFORMANCE FOR HIGH VOLTAGE, HIGH POWER APPLICATIONS

TYPICAL CHARACTERISTICS AT 25°C

	DT100	DT80	2N174A	2N174
Maximum Collector Current	15	15	15	15 amps
Maximum Collector Voltage (Emitter Open)	100	80	80	80 volts
Saturation Resistance	.02	.02	.02	.02 ohms
Thermal Gradient (Junction to Mounting Base)	.8	.8	.8	.8 °C/watt
Nominal Base Current I_B (V_{EC}=2 volts, I_C=5 amps)	135	100	135	135 ma
Collector to Emitter Voltage (Min.) Shorted Base (I_C=.3 amps)	80	70	70	70 volts
Collector to Emitter Voltage (Min.) Open Base (I_C=.3 amps)	70	60	60	60 volts

*Designed to meet MIL-T-19500/13A (Jan) 8 January 1958

HERE IS A LINE OF TRANSISTORS SPECIALLY DESIGNED FOR SWITCHING APPLICATIONS.

Check your switching requirements against the new characteristics of Delco High Power transistors. You will find improved collector to emitter voltage characteristics. You will find higher maximum current ratings—15 amperes. You will find that an extremely low saturation resistance has been retained.

Another important improvement is the solid pin terminal. And, as always, diode voltage ratings are at the maximum rated temperature (95°C.) and voltage.

Write today for engineering data on the *new* characteristics of *all* Delco High Power transistors.

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CIRCLE 66 ON READER-SERVICE CARD

NEW PRODUCTS

COMPUTER-DIRECTED PROCESS CONTROL offers three operating modes.

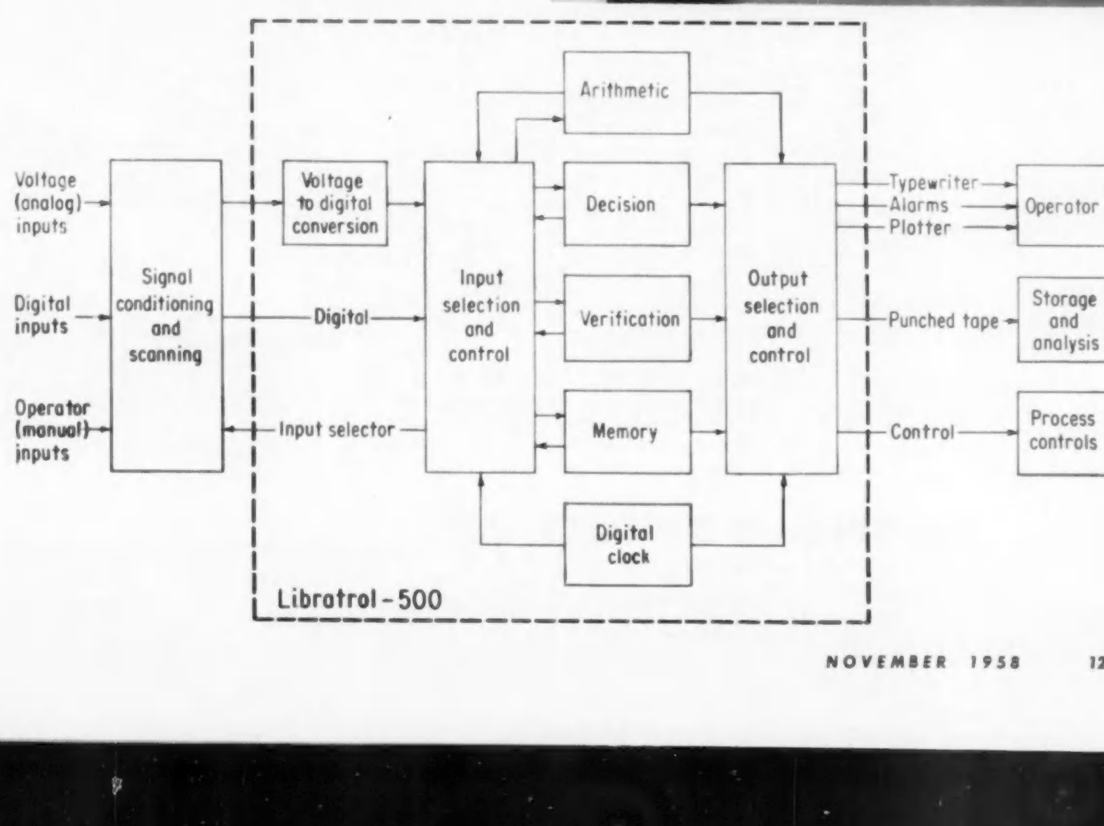
Built by Librascope and marketed by GPE Controls, the Libratrol-500 process control system permits control decisions at rates that match the process time constants. Its basic building block consists of a highly reliable digital computer designed specifically for the computation and control requirements peculiar to industrial processes. Computer operation is serial, single address, fixed binary point, with internally stored program.

As shown in the block diagram at the bottom of the page, the unit accommodates a wide variety of analog, direct digital, and manual input data. The computer proper handles 200 31-bit words per sec. Inputs are scanned and conditioned on command from the stored program, which directs both computation and control system operations. Drum storage capacity is 4,096 words. Computer outputs can include voltages to actuate control elements, digital data for presentation to operating personnel, and punched tape for storage or further analysis.

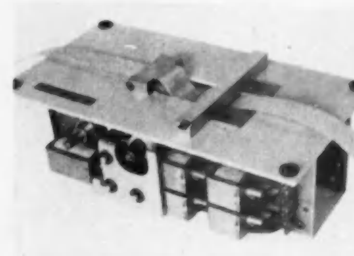
Flexible design of the unit provides for three distinct operating modes. As a data processor, the Libratrol-500 monitors the "on-stream" process, compiles various data, performs required computations, and presents this information to an operator. As a computer-directed controller, it calculates, on the basis of monitored data and stored logic, what the optimum set-points should be, and again presents this information to an operator. Finally, with the loop closed, it serves as an automatic process control system in which conventional feedback controllers provide instantaneous regulation while the computer carries out automatic trimming operations by continuously monitoring and adjusting set-points as calculations indicate.

Unit operates on a 115-volt, 60-cycle, single-phase supply, and draws 13 amp exclusive of power required for instrumentation, conversion, actuation, and other complementary equipment.—GPE Controls, Inc., Chicago, Ill.

Circle No. 200 on reply card



DATA HANDLING & DISPLAY



LOW-COST TAPE PUNCH

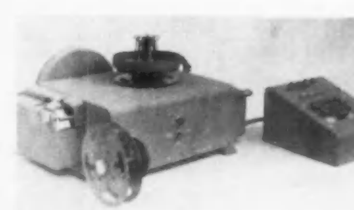
Designed for either console- or rack-mounting in a variety of data handling and communication systems, this new motorized tape punch handles any paper tape up to 1 in. wide. It operates on demand at speeds up to 27 cps, punching as many as eight columns of information. The unit measures only 6 by 11 by 3¾ in. and lists for just $295.–Precision Specialties, Inc., Kansas City, Mo.

Circle No. **201** on reply card

TAPE TRANSPORT

A fully-transistorized tape transport system, Model 424, records, stores, and reproduces analog or digital data. Two independent capstan drives with start-stop times of less than 2 millisec permit tape to operate in either direction at speeds between 60 and 150 ips. Features include modular construction, moderate power consumption, and storage bins for 3,000 in. of tape.–D.G.C. Hare Co., New Canaan, Conn.

Circle No. **202** on reply card



CHECKS TAPES

Pictured is the Model 244 Punch-Verifier, a new concept in off-line preparation of paper tapes. In two op-

erations, a tape can be punched and verified from the 10-key (plus special character) keyboard. During the checking operation, the keyboard locks if the key depressed and the tape in the verifier do not agree. If the keyboard is correct an override switch permits the operator to punch the correct digit; if the tape is correct, a reset button allows him to try again. —Digital Service Labs, Torrance, Calif.

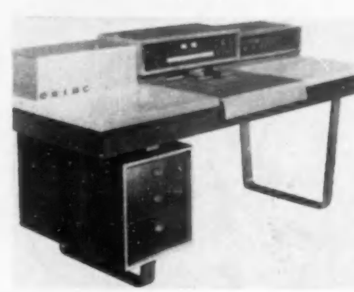
Circle No. 203 on reply card

PLUS . . .

(204) An all-electronic **digital voltmeter** by **Electronic Associates, Inc.,** Long Branch, N. J., features transistorized circuitry for maximum readbility and long life. . . . (205) **Beckman Instruments, Inc.,** Fullerton, Calif., offers the Beckman IR-7, a new prism-grating **infrared spectrophotometer** for molecular structure studies as well as routine quality control applications. . . . (206) Jointly developed by **Davis Instrument,** Newark, N. J., and **Greenbrier Instrument,** Ronceverte, W. Va., the Chroma-Cat **chromatographic analyzer** contains a highly-sensitive catalytic combustion cell in a system using air as a carrier gas. . . . (207) A new null-balance strip chart **recorder-controller,** recently announced by **General Electric Co.,** West Lynn, Mass., provides continuous standardization and is available in potentiometer or bridge versions.

Circle No. 204, 205, 206 or 207 on reply card

RESEARCH, TEST & DEVELOPMENT

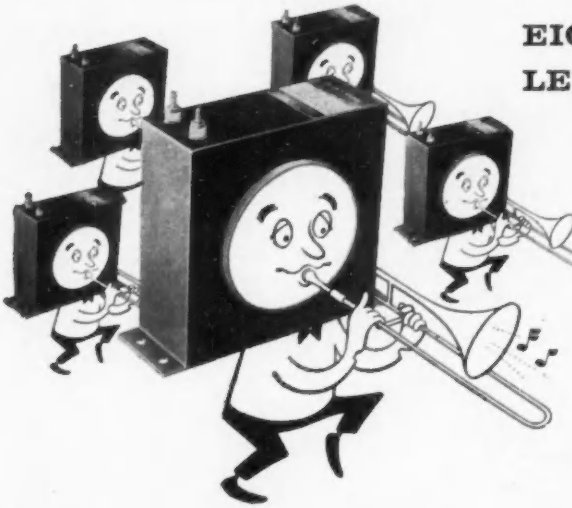


DESIGN AID

The ESIAC, a new analog computer for calculating and plotting values of algebraic functions of a complex variable, suits a wide variety of engineer-

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

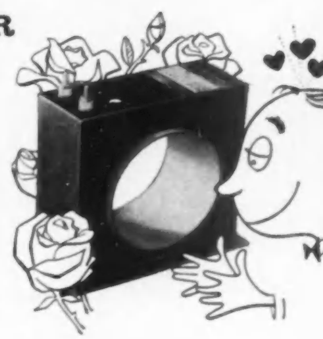
For Control Engineers Who Are Wearing Out Before Their Time



EIGHTEEN TRANSDUCTORS LED THE BIG PARADE!

Some strip-plating friends of ours had to control currents flowing to eighteen anodes. To regulate the plating thickness, they had to sum the individual large (up to 7500 amperes d-c) currents, without interfering with the accurate metering of each one individually. Were they ever pleased to find that each of their eighteen CONTROL transductors (which never wear out) would eliminate special metering, and would also drive a heavy duty overload relay . . . contribute its share of power to an a-c totalizing transformer . . . and permit instrumentation currents to be carried great distances to switchboard panels with proper safety isolation and no loss of accuracy. *They said we could tell you, if you wanted more information, that they did away with shunts, too! Need more details?*

A TRANSDUCTOR IS A TRANSDUCTOR IS A TRANSDUCTOR



Truth is there are people who think we are saying "transducers" when we are saying "transductors." 'Tisn't so. Our CONTROL transductors are simple saturable reactors which (oh, joy!) never need maintenance. We connect two Orthonol cores in series opposition, and run the bus bar, whose current we want to measure, through them (giving us, essentially, a one-turn control winding). Don't even have to make a direct electrical connection—and we wind up with enough output for instrumentation, and plenty left over for feedback control. *Try that on a transducer sometime. Or a shunt-millivoltmeter, for that matter. Whatever you want to try it on, you can try us for full information first.*

WE HAVE TROUBLE WITH LIFE TESTS

One of the fine technical magazines in which this Journal appears recently did a survey on reliability. They wrote us and asked how long our CONTROL transductors would last under certain conditions. It was sort of embarrassing. How can you run a life test on something that won't wear out? You see, our transductors have no moving parts, no filaments to burn out, nothing to replace or maintain. Bury them in the ground or install them in the corrosive atmosphere of a chlorine plant—it makes no difference. We told the editor what our problem was, and he said, "Hmmmm, I see." Now we're waiting to see what he's going to say about this remarkable step forward in reliability. *If you have to measure or record from 200 to 10,000 amperes with isolated meters, there's a world of information awaiting your inquiry. And it may give your maintenance man a break, too!*

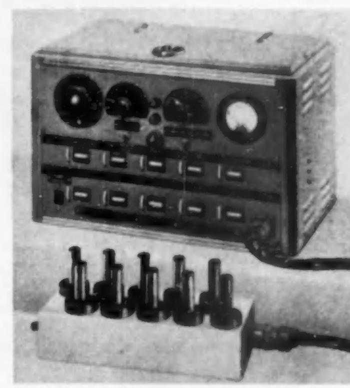
Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC.

Dept. CE-53, BUTLER, PENNSYLVANIA

ing applications: servomechanisms design, analysis of electromechanical and electro-acoustical devices, network synthesis, and other problems requiring the solution of Laplace transforms of linear differential equations. In frequency response analysis, the unit scans the real frequency axis, plotting gain or phase as a function of frequency, and yields measures of system stability such as Q, phase margin, gain margin, and attenuation rate.—Electro Measurements, Inc.

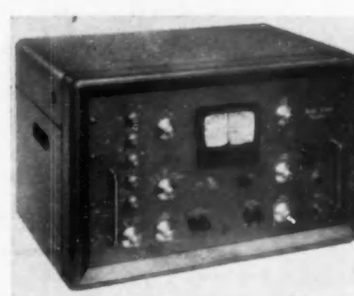
Circle No. 208 on reply card



RELAY TEST SET

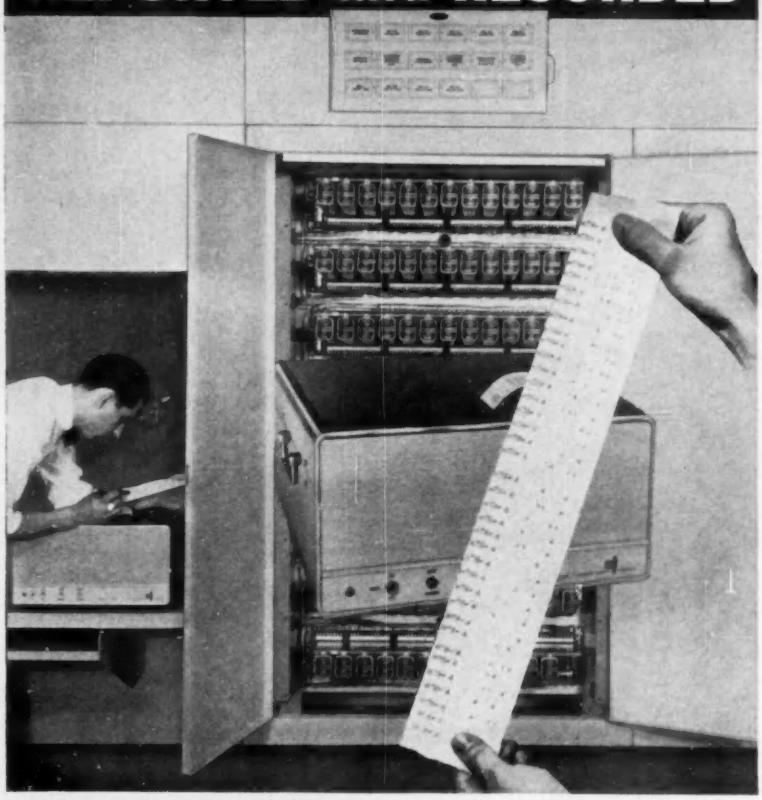
Unit shown checks up to 10 relays simultaneously for normal operate time, saturate release time, or release time after predetermined heating. A built-in variable power supply provides energizing voltages, continuously adjustable over a 2.5-to-230-volt range. Set operates from a 115-volt, 60-cycle supply. Standard test panel takes seven-pin miniature relays with either plug-in pins or hooked solder terminals.—G-V Controls, Inc., East Orange, N. J.

Circle No. 209 on reply card



CHECKS TRANSISTORS

Designed specifically for analyzing time characteristics of high-speed



transistors, this instrument will measure switching time on the leading or trailing edge of an output pulse with an error of 3 μsec in the 3-to-100 μ range. In operation, an extremely precise driving pulse is applied to the transistor under test. By comparing its output pulse with a pulse having known characteristics, the unit converts time to a voltage whose amplitude is proportional to duration. This voltage is amplified and displayed on a meter.—Atronic Products, Inc., Bala-Cynwyd, Pa.

Circle No. 210 on reply card

PLUS . . .

(211) **Eder Engineering Co.**, Milwaukee, Wis., has announced a new **precision torque balance** for measuring reactance and stall torques of precision gyro motors. . . . (212) To blanket the field of dc measurement, **Keithley Instruments, Inc.**, Cleveland, Ohio, developed the Model 600 **portable electrometer,** an instrument with 53 different ranges . . . (213) The Model 194 **continuous-writing streak camera,** produced by **Beckman & Whitley,** San Carlos, Calif., plots space vs. time in the study of explosions, shock-tube manifestations, and flash-tube and spark-discharge phenomena. . . . (214) **National Instrument Laboratories, Inc.,** Washington, D. C., recently introduced a new line of self-contained, portable **gas flowmeters** for field-checking such things as other flowmeters, valve leakage, pump output, and flow controller action.

Circle No. 211, 212, 213 or 214 on reply card

PRIMARY ELEMENTS & TRANSDUCER

ONE-SHOT T'COUPLES

An expendable immersion thermocouple has been designed for measuring temperatures in molten steel. This one-shot item is said to be comparable in cost with present methods since maintenance and contamination problems are eliminated and accuracy improved. Equipment consists of a length of pipe with a handle on one end and a fitting on the other to hold the expendable cartridge. The later is a refractory cylinder with contacts at the receptacle end and a sheathed thermocouple on the immer-

sion end. A sheet-steel cap which melts away in the molten steel provides protection before use and permits the thermocouple to pass through slag and other floating solids before being exposed.—Leeds & Northrup Co., Philadelphia, Pa.

Circle No. 215 on reply card

SILICONE DAMPED

High transverse stiffness of its self-compensating *E* springs greatly reduces the cross-sensitivity of the Type TA2 accelerometer. Total immersion in a carefully selected silicone fluid provides a damping ratio of 0.65. Expansion chambers in the case compensate for volumetric changes and permit an operating temperature range of minus 40 to 100 deg C. The use of dual pots assures high level, redundant output. Life tests reveal that units can withstand 10 million reversals without losing calibration.—Lind Corp., Princeton, N. J.

Circle No. 216 on reply card

COMPACT PICKUP

The Model S-40 dual-coil, variable-reluctance pressure transducer, designed for high stress environments, combines low sensitivity to shock, vibration, and acceleration with a rise time of approximately 150 μsec. Ab-

solute, differential, and gage models are available in 11 ranges from 0.1 to 5 psi. With input frequencies between 400 cps and 40 kc, the S-40 gives exceptionally high output, e.g. 150 mv/v into a 1,500-ohm load. Standard operating temperature range is minus 85 to 240 deg F.—Ultradyne, Inc., Albuquerque, N.M.

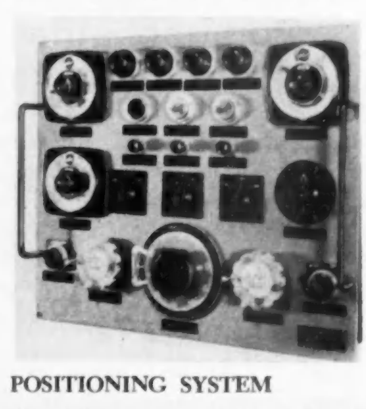
Circle No. 217 on reply card

PLUS. . . .

(218) A new flanged all-metal Bayard-Alpert type **ionization gage** with either nonburnout iridium or double tungsten filament is now available from **Veeco Vacuum Corp.**, New Hyde Park, N. Y. . . . (219) The Dynisco PT49 water-cooled **pressure transducer,** by **Dynamic Instrument Co., Inc.,** Cambridge, Mass., has been designed specifically for use in rocket research and has withstood continuous test temperatures in excess of 5,000 deg F. . . . (220) **Schaevitz Engineering,** Camden, N. J., announces a new **rotary variable differential transformer** for angular position measurements. . . . (221) **The Pottermeter Co.,** Union, N. J., has introduced a series of **turbine-type meters** for gas flow measurements over a range from 0.03 cfm to 30,000 cfms.

Circle No. 218, 219, 220 or 221 on reply card

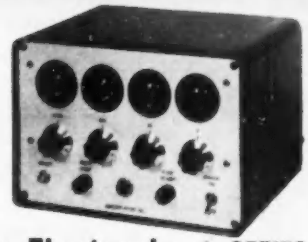
CONTROLLERS, SWITCHES & RELAYS



POSITIONING SYSTEM

Pictured is a new automatic point-to-point positioning system featuring simple dial-set analog programming. Designed chiefly for automating short-run production jobs, the system uses

NEW Veeder-Root Counters



New Electronic / SERIES 1604 Predetermining Counters

These counters are ideal for batch control, sequential predetermining, or accurate length control in such applications as packaging, coil winding, slittling, stacking and material handling.

A versatile group of transistorized electronic predetermining counters designed particularly for industrial applications. These units will operate at speeds up to 5,000 counts per second, with automatic recycling at speeds up to 1,000 counts per second. A photohead to actuate the counter can be designed to fit specific applications.

Units can be easily operated by non-technical personnel. The preset quantity can be established quickly at any point within the range of the counter by means of the large selector knobs. Any number of decades can be furnished.

Dual sets of presetting controls for sequential predetermining, or accurate length control in such applications can be furnished on request.

This is your complete package for predetermining counting at high speeds.

For complete details on these units, write today!

Count-PAK / SERIES 1661

Complete electronic counting package for use where high speed, long life and instant reset are required. Highly suitable for high speed direct counting applications such as can and bottle counting or case or piece counting on conveyor lines.

Consists of glow-transfer cold-cathode counting tube and high speed magnetic counter, coupled with transistorized circuits. Photohead designed to your application.

The use of transistors means that heat has been eliminated and no warm up time is required. Unit is completely enclosed in an attractive industrial case to insure long, trouble-free life. Use of an electronic decade increases the life of the electro-mechanical counter and makes the unit ideal for continuous rugged operation.

Write for complete specifications and prices today!

NEW SERIES 1522 High-Speed Predetermining Counter

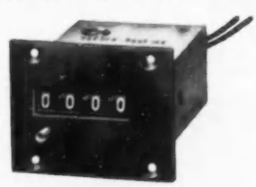
Ideal for high-speed counting requirements such as coil winding, textile spinning frames, and other predetermining counter requirements.

Instant quick-lever reset, plus quick and easy setting of the predetermined number are outstanding features of this counter. Measures approximately 2.6" wide, 5" long, 2.8" high. Speeds up to 6,000 RPM or 8,000 CPM are maximums recommended.

Easily preset to the required number of pieces or performance-units, the counter subtracts to zero. Resetting returns wheels to original preset number. This new counter meets standard U. S. electrical requirements (JIC Codes) . . . and is available with either electrical switch or mechanical stop. Also available without the predetermining feature, as a high speed reset revolution counter.

Also available as a high-speed revolution counter without predetermining feature.

Write for complete information today!



SERIES 1591 / Electro-Magnetic Counter

These new compact panel-mounted high speed counters are ideal for D.C. applications requiring accuracy, long life at high speeds and small panel presentation. Counters are suitable for industrial data processing, laboratory and scientific or instrument applications. Available with four or six figures with remote electrical or manual (push button) reset. 3,000 counts per minute recommended speed.

Counters can be connected in series with any device having a contact arrangement. For optimum operation, 60% contact time is required.

Panel Area: 4-figure Counter — 1.7" x 2.1"
6-figure Counter — 1.7" x 2.8"

Available for 6, 12, 24, 48 and 115 volts D.C. operation. For A.C. operation suitable electrical components must be added externally. Reset voltages available are 6, 12, 24, 48, 115 and 230.

Write for complete specifications today!

Veeder-Root
INCORPORATED
HARTFORD 2, CONNECTICUT
Hartford, Conn. • Greenville, S. C. • Altoona, Pa. • Chicago • New York
Los Angeles • San Francisco • Montreal • Offices and Agents in Principal Cities

CIRCLE 79 ON READER-SERVICE CARD

NEW PRODUCTS

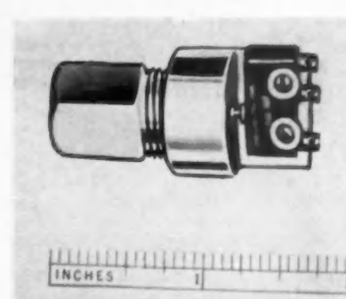
direct, uncoded programming for repetitive and symmetrical motion patterns. In operation, dial settings control high-performance electrohydraulic servos, which in turn position the tools involved. Servo systems provide an operating period of 0.2 sec per basic motion and an accuracy within 1 part in 1,000. Because of its analog input, the system offers infinite adjustability for both longitudinal and transverse movements.—CDC Control Services, Inc., Hatboro, Pa.

Circle No. 222 on reply card

HAS MANUAL RESET

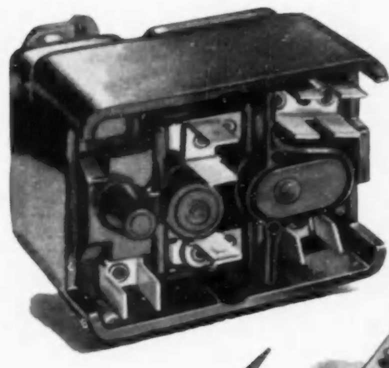
Designed to comply with MIL-R-5757 and MIL-R-6106, this miniature impulse latching relay operates on 15 millisec pulses and is available for 60-to-400-cycle operation, internally rectified. Temperature range is minus 65 to 125 deg C.—Electro-Mechanical Specialties Co., Los Angeles, Calif.

Circle No. 223 on reply card

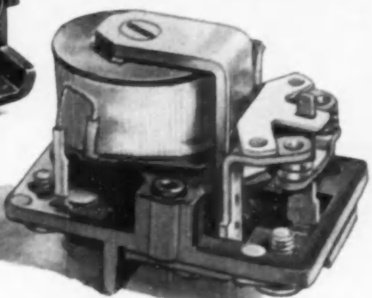


WEIGHS ONE OUNCE

Under 1 in. in diam and less than 1¾ in. long, this lightweight pressure switch operates on pressures between 25 and 1,000 psi and has an over pressure rating to 3,000 psi. Switch uses spdt contacts rated at 5 amp, 240 vac, provides a ⅛ in. NPT inlet



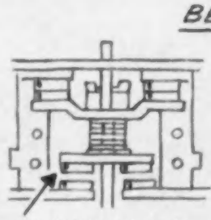
RBM SERIES 128000 Potential Type Motor Starting Relays



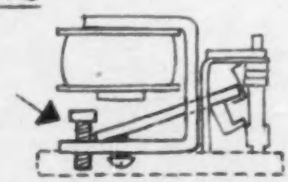
A highly efficient, dependable relay for starting single phase capacitor type motors, where use of centrifugal switch is impractical. Normally closed contacts disconnect start capacitor from circuit at desired switching speed. Standard contact arrangement is single pole normally closed. Listed by U/L File No. SA 1984.

MEETS STRINGENT REQUIREMENTS OF COMPRESSOR, MOTOR, PUMP, AIR CONDITIONING MANUFACTURERS

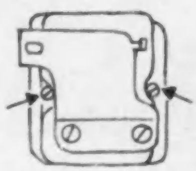
BENEFITS



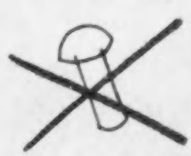
EXTRA NORMALLY OPEN CONTACTS (SPDB) AVAILABLE FOR SEQUENCE STARTING



ADJUSTMENT BY "FLUX SHUNT" IN MAGNETIC CIRCUIT



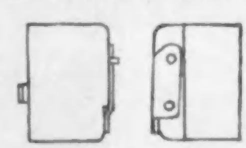
COVER HELD FIRMLY BY 2 SCREWS



NO CURRENT CARRYING RIVETS IN CONTACT CIRCUIT

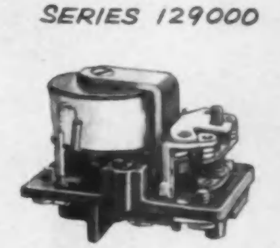
AVAILABLE WITH SCREW OR QUICK CONNECT TERMINALS

LARGE DOUBLE BREAK CONTACTS. POSITIVE BALANCED HAMMER BLOW ACTION



VARIETY OF MOUNTING BRACKETS AVAILABLE

GENERAL PURPOSE SHUNT TYPE RELAY SERIES 129000



INCORPORATES ALL 128000 FEATURES, EXCEPT OPERATING COILS ARE DESIGNED FOR STANDARD COMMERCIAL VOLTAGES. (OTHER COILS AVAILABLE FOR SPECIAL APPLICATION). CONTACT RATINGS 18 AMP AT 250 V. OR 1 H.P.-125 V. SINGLE PHASE; 2 H.P.-250 V. SINGLE PHASE. LISTED BY U/L FILE NO. E-12139.

Consult Your Local RBM Product Application Engineer or Write For Bulletin 1010A.

RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

CIRCLE 81 ON READER-SERVICE CARD

opening, and operates in any position. —Alloy Bellows, Inc., Cleveland, Ohio.

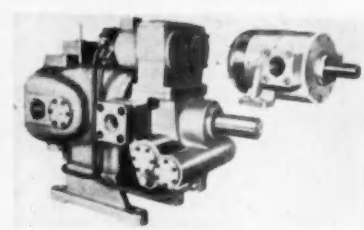
Circle No. 224 on reply card

PLUS . . .

(225) A pneumatic time delay relay which requires no extra vertical space has been added to its line of 10-amp relays by **Clark Controller Co.,** Cleveland, Ohio . . . . (226) **Automatic Timing & Controls, Inc.,** King of Prussia, Pa., has gone into quantity production of the Type 2782 **proximity limit switch,** a new unit capable of detecting magnetic materials through a 1-in. air gap. . . . (227) **General Electric Co.,** Schenectady, N. Y., now has a transistorized **photoelectric relay** for heavy-duty industrial service. . . . (228) A brand new line of explosion-proof **timing controls,** introduced by **Industrial Timer Corp.,** Newark, N. J., includes single- and multi-cam types with up to 19 switches and time cycles from ¾ sec to 72 hours. . . . (229) **Automatic Switch Co.,** Florham Park, N. J., offers a 24-volt ac **control center** for safer operation of remote control switches in power and lighting circuits.

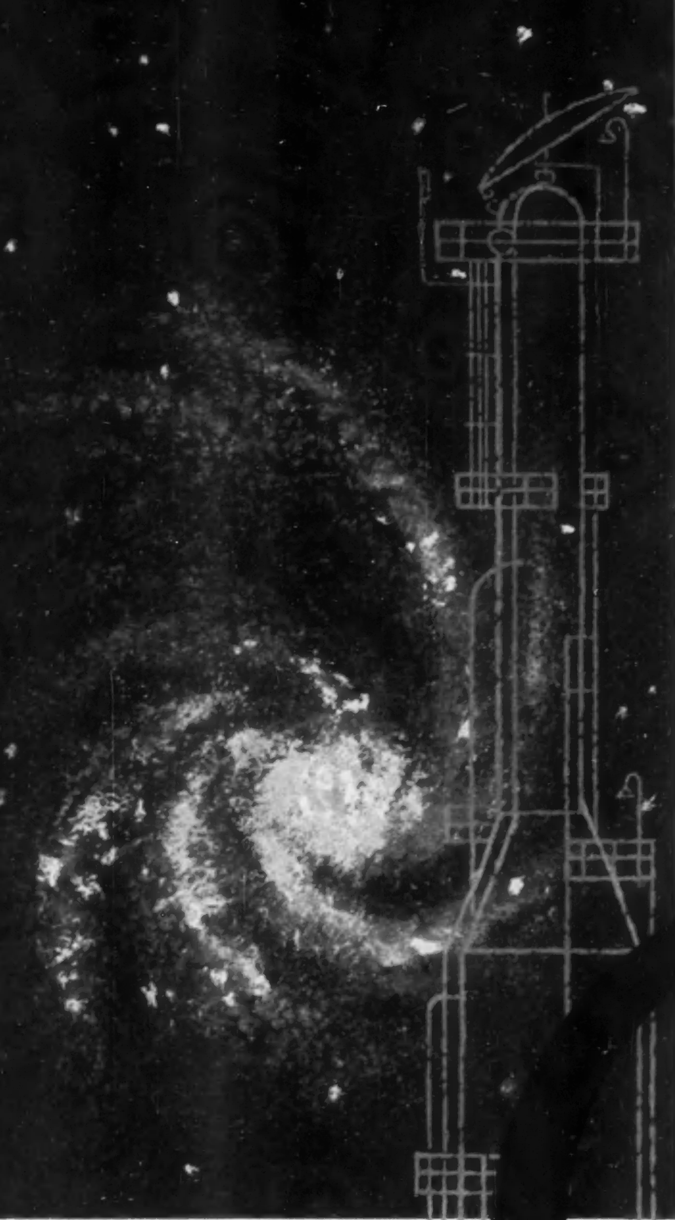
Circle Nos. 225, 226, 227, 228, or 229 on reply card

POWER SUPPLIES



HIGHLY EFFICIENT

A brand new line of axial piston pump and motor sets features overall mechanical efficiencies of 92 percent and volumetric efficiencies of 96 percent. Available in three series, the line covers both constant volume and variable volume types. Operating pressure of these units is 3,500 psi with intermittent overload to 4,500 psi. A shaft-driven, servo-replenishing pump provides supercharging, pressure control, and forced circulation for cooling. It also supplies the closed circuit with oil required for normal operational slippage. Navy approved, the units serve as power supplies in the hydraulic control of missile launching and handling devices, fire control sys-



Genesis of a GENESYS System

This Dynamic Memory Processor is a nucleus product creation of the Genesys Corporation. No product has ever approached all of its performance capabilities. A unique building block of advanced Genesys Systems, it achieves *seven giant steps forward* in economic, reliable process control using a minimum of associated hardware:

. . . stores a vast amount of control capability on a simple, reliable memory surface

. . . monitors, stores, logs information of any process or fabrication system

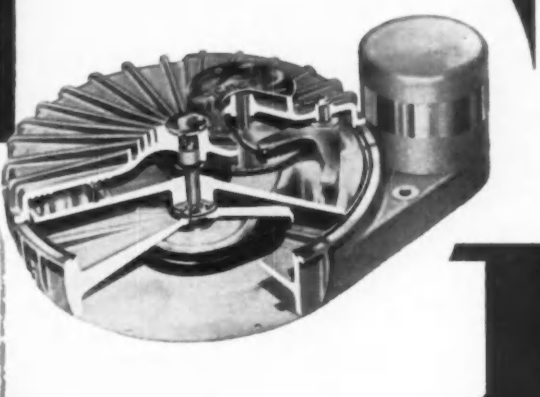
. . . makes correlative decisions

. . . performs extensive computation in the memory

. . . decides on "system optimization" control through learning logic

. . . assumes direct control of actuators and power elements

. . . checks itself automatically for optimum reliability



GENESYS CORPORATION

10131 National Boulevard • Los Angeles 34 • California

ADVANCED CONTROL COMPUTER SYSTEMS *for the petroleum, chemical and petrochemical industries*

CIRCLE 83 ON READER-SERVICE CARD

tems, and marine steering equipment. —American Brake Shoe Co., Columbus, O.

Circle No. 230 on reply card

BUILT-IN PROTECTION

Shown is one model in a new line of portable, transistorized power supplies. Units feature a patented protective circuit that cuts out the supply within 30 μsec after an external short occurs. The supply cannot be turned on again as long as the short persists. Characteristics below pertain to the unit shown, Model 1515.

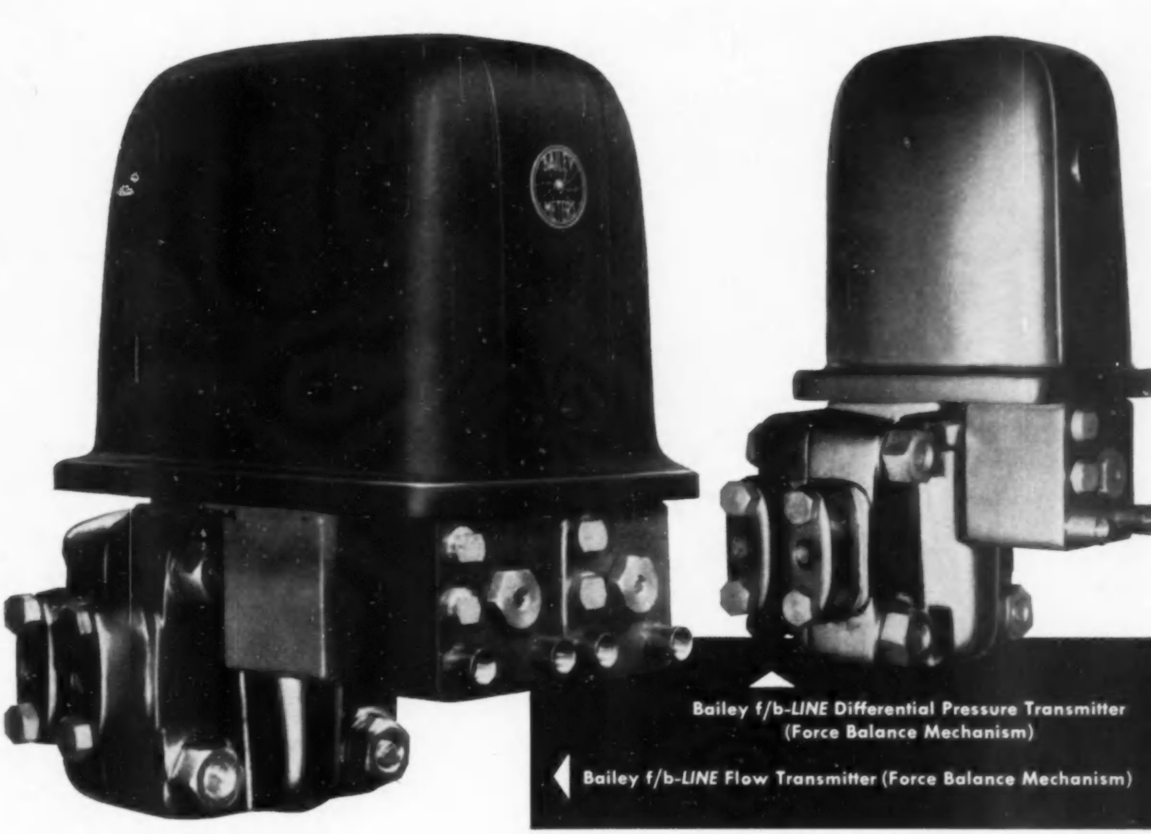
Characteristics:

Voltage range: 1-15 vdc
Current range: 0-1.5 amp
Regulation: within 0.05 percent
Ripple: less than 250 μv
Response time: less than 50 μsec
—Power Designs Inc., Richmond Hill, N. Y.

Circle No. 231 on reply card

5½-POUND SUPPLY

This all-transistor, 12-vdc power supply is designed to save batteries in test equipment wherever line power is available. It handles any four instruments simultaneously without interaction from common power-supply impedance. Four outputs on the front


Bailey f/b-LINE Differential Pressure Transmitter (Force Balance Mechanism)
Bailey f/b-LINE Flow Transmitter (Force Balance Mechanism)

panel are individually filtered, and an additional filter is provided for the power-supply proper. Unit measures 6 by 8 by 6¼ in., uses printed circuitry and dependable miniature components.—Consolidated Electrodynamics Corp., Pasadena, Calif.

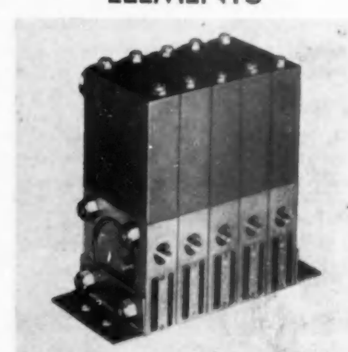
Circle No. 232 on reply card

PLUS . . .

(233) **Sila-Kon Engineering Co.**, El-Monte, Calif., has a regulated **dc power supply** featuring transistorized circuits and a built-in adjustable overload protection system. . . . (234) A 0-to-18-volt, 0-to-1-amp **supply** with less than 1 mv ripple is now available from **Kepco Laboratories, Inc.**, Flushing, N. Y. . . . (235) **General Electric Co.**, Schenectady, N. Y., announces a line of **adjustable speed drives** in the 10 to 200 hp range that use power amplistat regulation for long life and greater reliability. . . . (236) Another **tubeless power supply**, the Model RM-1A by **Nutron Mfg. Co.**, Staten Island, N. Y., provides dc and ac voltages, continuously variable from 0 to 120 volts; current rating of 1 amp at any setting.

Circle No. 233, 234, 235, or 236 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

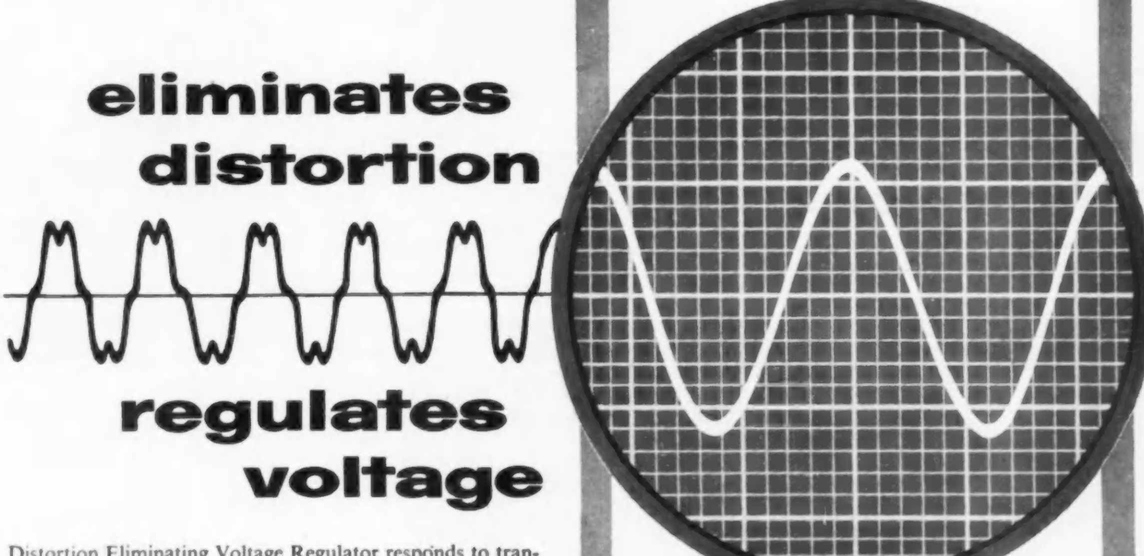


THIN SOLENOID VALVE

Only 1 in. thick, 3 in. wide, and $6\frac{1}{16}$ in. high, the S-3C-S solenoid-operated valves mount in limited space and are ideal for manifolding. Photo shows five units arranged for multiple operation. They are tapped for ⅛ or ¼ in. pipe connections and are suitable for use with air or oil at pressures to 125 psi and tempera-

NEW 400 cycle DEVR

eliminates distortion



regulates voltage

Distortion Eliminating Voltage Regulator responds to transient surges and harmonics, as well as to normal variations caused by line and load changes. The Curtiss-Wright Model 104 DEVR corrects for any deviations of up to 20% from pure sine wave, regardless of their nature, in less than 125 microseconds.

It provides the answer where line fluctuations or distortion cause inaccuracies and loss of engineering and production man-hours in the design and manufacture of electronic systems for aircraft and missiles. In servos and computers, and wherever summing operations are performed, the Model 104 DEVR assures increased accuracy and stability. It is invaluable for standards laboratories and others where accuracy of instrumentation is pushed to extremes; it also increases equipment life by eliminating surges.

Write today for complete information. Price: $1875 f.o.b., Carlstadt, N. J.

The DEVR is also available in 60 cps model.

SIMULTANEOUSLY AVAILABLE

- **1.4 KVA** — regulation ±1% electronically; response 125 microseconds; distortion elimination to less than 0.3%
- **4 KVA** — regulation ±1% electro-mechanically; response 20 V/sec

ELECTRONICS DIVISION

CURTISS-WRIGHT

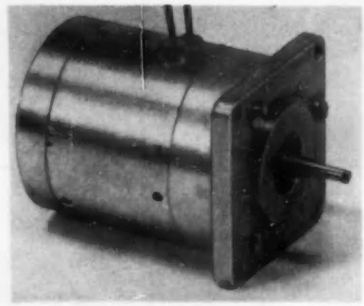
CORPORATION • CARLSTADT, N. J.

CIRCLE 87 ON READER-SERVICE CARD

NEW PRODUCTS

tures to 150 deg. F. Ratings at 120 psig air are 300 cpm continuous, 700 cpm intermittent. Four through holes and a 1¾ in. sealed counterbore permit manifolding in any of four positions. Hunt Valve Co., Salem, Ohio.

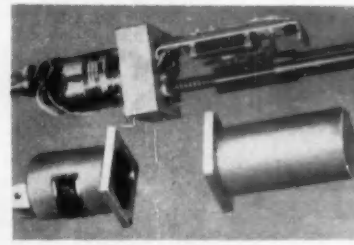
Circle No. 237 on reply card



TAKES 40-DEG STEPS

This new stepping motor, measuring 1¼ in. in diam by 1⅞ in. long, provides nine 40-deg steps per revolution. Tests indicates a life expectancy of 24 million steps. At 17.5 watts input the motor will produce 2.5 oz-in. of torque and follow a 25-cps pulse with a low-torque, low-inertia load. At 45 watts input and an adjusted air gap the unit will produce 5.5 oz-in. and follow a 50-cps pulse with low-inertia loads. Where desired, the unit can be furnished with special switches.—Globe Industries, Inc., Dayton, O.

Circle No. 238 on reply card

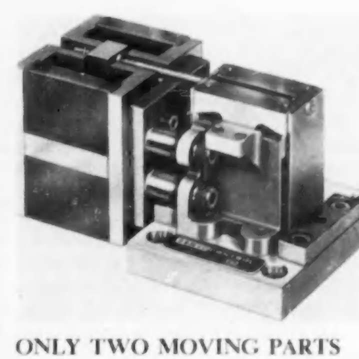


COMPACT SERVO

Designed to actuate drone aircraft and missile control surfaces, this new lightweight servo develops from 50 to 800 lb thrust in converting rotary motion in precise relation to a low-voltage dc input. Its transistorized amplifier, not shown, requires only about 25 cu in. of space. Positioning unit measure 9½ in. between mounting centers, has a 2½-in. square center block, and 2-in. diam covers. A feedback error of 2 vdc or 50 μ amp applies full torque to the motor.

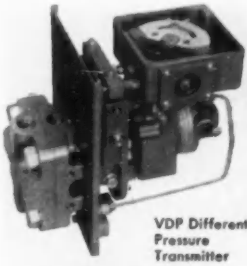
Characteristics:
Travel: 1¼ in., std model
Max velocity: 5½ in. per sec, no load
Stalled thrust: 150 lb
Repeatability: within 0.007 in.
Frequency response: 8-12 cps
—Advanced Research Associates, Inc., Kensington, Md.

Circle No. 239 on reply card

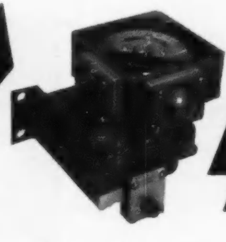


ONLY TWO MOVING PARTS

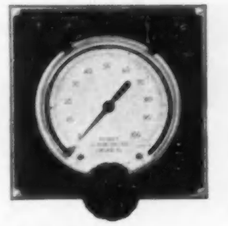
Pictured is brand new concept in single-stage, three- and four-way electrohydraulic control valves. The servovalve contains only two moving parts: a torque motor armature and a "swing plate". Because the latter makes no contact with the valve body, it permits high sensitivity and fast response



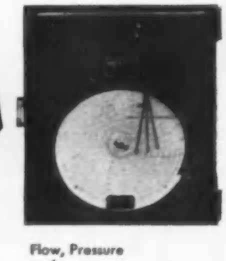
VDP Differential Pressure Transmitter



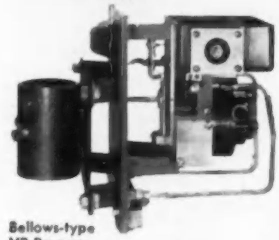
VC Controller



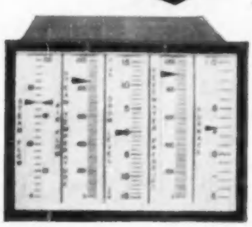
Type "A" Control Station



Flow, Pressure and Temperature Recorder



Bellows-type VP Pressure Transmitter



V-5 Gauges

Series 775 Final Drive

Diaphragm-type Angle Valve

NOW—
Control In Any Dimension

with *standard* *Republic components*

In order to fit your exact process control requirements, Republic now offers you a *complete* range of basic control components, which are (1) extremely accurate, (2) unusually versatile and (3) remarkably easy to combine into control systems.

For example: The differential pressure transmitter and controller illustrated are part of *a new family of pneumatic instruments*, developed to use the greatest possible number of *common* components. Because these Vector Series components can be interchanged—even among instruments performing entirely different *functions*—training and parts inventory are greatly simplified.

Radical changes in plant operating conditions present no problem when Vector instruments are used. Proportional band of the controller, for instance, is continuously adjustable from 2 to 500 per cent; the differential pressure transmitter has a range adjustment of 20 to 1, the pressure transmitter of as much as 10 to 1. Such adjustments are made simply by moving a link held by a lock screw. Re-zeroing is seldom needed.

Multi-point gauges with self-contained measuring elements are available for pressure, vacuum and differential. May also be used as receivers to indicate flow, CO_2, temperature or liquid level. Units may be grouped in any combination and substituted without disturbing other gauges. One- to four-pen recorders also available to measure these values.

Versatile Republic final drive units operate dampers, valves, inlet vanes and many other mechanisms. May be locally or remote controlled, by manual or automatic means. Proportionality of signal response can be tailored by a cam shaped on the job.

These are only a few of the many reasons why it is well worth while to consider versatile Republic components for your next (or existing!) control system. Your nearest Republic Sales Office will be delighted to assist . . . or contact Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois. In Canada: Republic Flow Meters Canada, Ltd., Toronto. (Subsidiary of Rockwell Manufacturing Company)

REPUBLIC INSTRUMENTS AND CONTROLS

more fine products by

ROCKWELL

while eliminating sticking, scoring, and jamming.

Characteristics:

Flow rate: 4 gpm at 250-psi drop and 8 gpm at 1,000-psi drop
Supply pressure: to 3,000 psi
Torque motor force: 11 lb-min at mid-position
Power demand: 5 watts max
Stroke: plus or minus 0.015 in.
–The Oilgear Co., Milwaukee, Wis.

Circle No. **240** on reply card

PLUS. . . .

(241)**The Galland-Henning Nopak Div.**, Milwaukee, Wis., recently announced the addition of six models and additional bore sizes to its line of 3,000-psi, Class 3, square-head **hydraulic cylinders**. . . . (242) The Type 1000 **control valve,** offered by **Uniflow Valve Corp.**, Cranford, N. J., features a new springless-diaphragm motor operator using pre-formed Buna-N-Nylon diaphragms. . . . (243) **Hoover Electric Co.**, Columbus, Ohio, has developed a lightweight 1-hp, 22,000-rpm, 400-cycle, 208-volt, three-phase **ac motor** for missile applications.

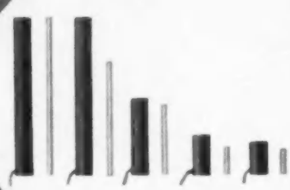
Circle Nos. **241, 242,** or **243,** on reply card

SANBORN *Transducers*

FOR LINEAR MEASUREMENTS...

DISPLACEMENT

LINEARSYN Differential Transformers



Six series of Sanborn Linearsyns — three of the shielded type, three unshielded — are available, with five models in each series. Linearity is better than 1% of full scale output in all models. Temperature range is from −50° to 205°F.
Special design features include coil assemblies hermetically sealed in epoxy, laminated phenolic jackets (unshielded types) or heavy plated steel jackets (shielded types), improved lead wire strain relief, high permeability alloy cores. Models with axial leads are also available on special order. Within each series all models have identical diameters, tap sizes, lead wires; only the lengths of coil assemblies and cores vary.

Typical Linearsyn Characteristics

Series* (Unshielded)	Series* (Shielded)	Strokes* (±Inches)	Freq. Ranges	Sensitivities* (Volts/inch per volt of excitation at std. carrier freq.)
575DT	585DT	.050 - 1.00	400 cps - 10 kc	.56 - 3.70
576DT	586DT	.050 - 1.00	60 cps - 400 cps	.70 - .90
590DT	595DT	.005 - .100	400 cps - 20 kc	1.60 - 2.60

*Maximum and minimum values available within each series, data on individual models on request.

VELOCITY

LVsyn Velocity Transducers

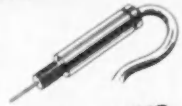
LVsyn pickups may be used to measure *linear velocity* directly, *displacement* with a simple integrating circuit, or *acceleration* with a differentiating circuit. There are twenty-four models, all self-generating with shielded cylindrical coil assemblies and high coercive force permanent magnets. Twelve models use regular magnet cores; twelve have *non-breakable* magnet cores. Characteristics of the two groups are the same except for output sensitivity, core length and weight. Features include high sensitivity, single-ended or push-pull output, accurate and stable calibration, unlimited resolution, wide range of sensitivities and sizes, temperature range of −50° to 200°F. They can be immersed in hydraulic fluid. No mechanical connection between coil and core permits low friction level. End stops or displacement limits not needed; undamaged if limits are extended.

Typical LVsyn Characteristics

Model	Displacement: Nominal Working Range (Inches)	Displacement: Maximum Usable Stroke (Inches)	Electrical Characteristics: Voltage Output mv/inch	Electrical Characteristics: Total Impedance Series Connection R ohms	Electrical Characteristics: Total Impedance Series Connection L henrys
3LVA5*	0.50	1.30	120	2,000	0.085
6LV2*	2.0	3.4	500	19,000	2.4
6LV2-N	2.0	3.4	250	19,000	2.4
7LV9*	9.0	11.0	350	17,000	2.8

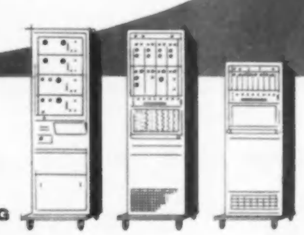
*Four of the twenty-four models available, selected to show minimum, approximate mid-range and maximum working ranges as well as the difference in sensitivity between a regular magnet core model (6LV2) and a non-breakable magnet core model (6LV2-N).

NEW!



COMPLETE DISPLACEMENT TRANSDUCER

"Probe" style, uses differential transformer. With cable and adapter for connection to Sanborn 150, 350 Series Carrier Amplifiers. Stroke ±0.070", high sensitivity, linearity 0.5%, infinite resolution, contact pressure as low as 10 grams. Stainless steel body, carbide tipped contact rod, jeweled bearings. Two models: 580—plug-in cable, flange mounting; 581—miniature, integral cable.



for MULTI-CHANNEL RECORDING

Sanborn direct writing systems now include 1- to 8-channel "150" Series, with a choice of 12 plug-in Preamplifiers; new single-cabinet, compact 6- and 8-channel "350" and "850" Series with interchangeable Preamplifiers, flush-front recorder with electrical pushbutton chart speed control and transistorized Power Amplifiers, and numerous features for high reliability and operating convenience.

For complete facts, call your local Sanborn Industrial Sales-Engineering Representative or write the Industrial Division in Waltham.

(All data subject to change without notice)

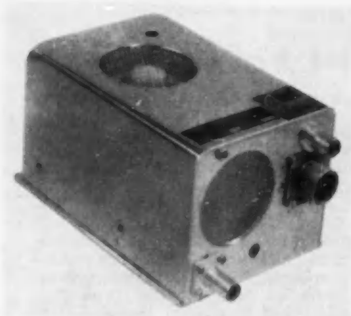
SANBORN COMPANY

Industrial Division
175 Wyman Street, Waltham 54, Mass.

CIRCLE 94 ON READER-SERVICE CARD

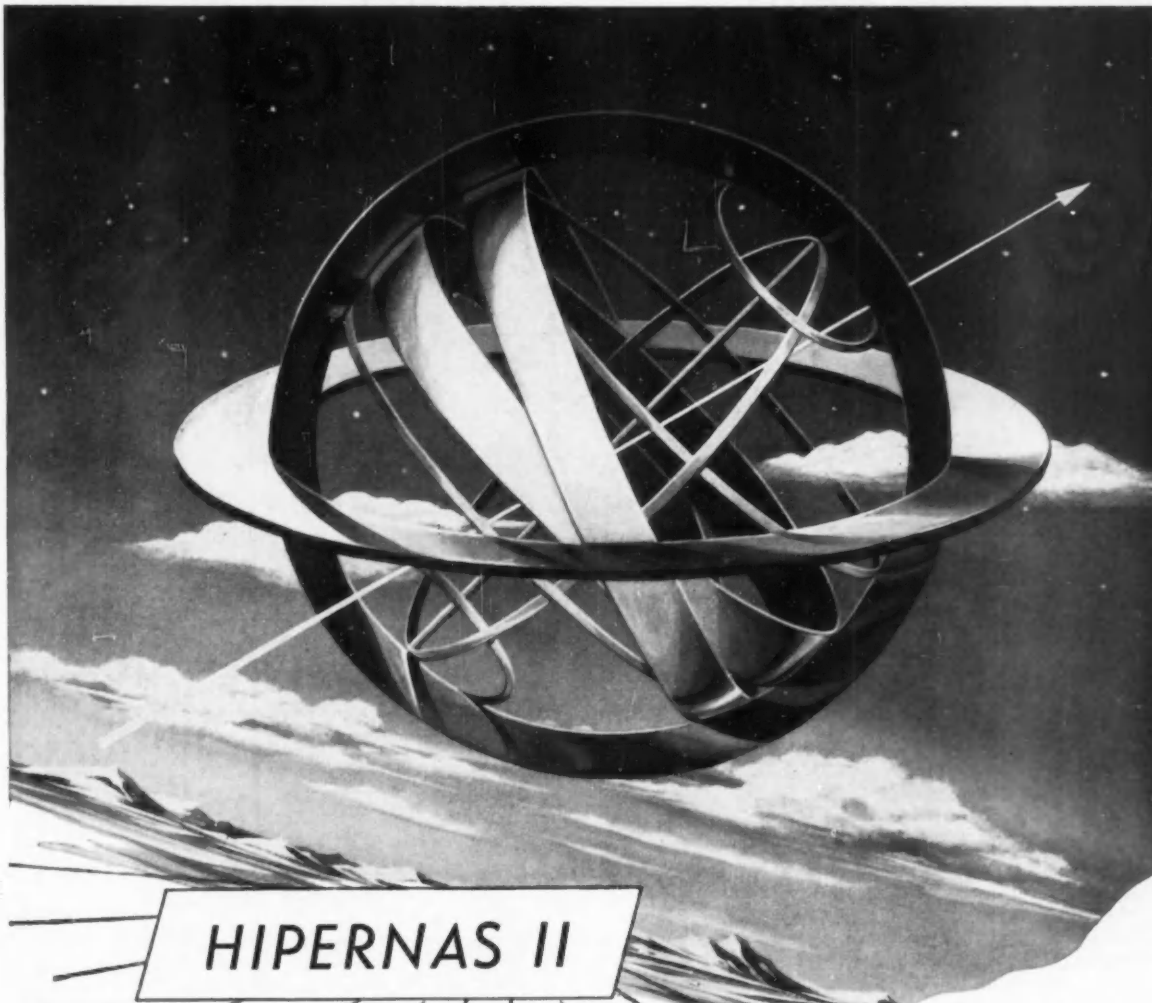
NEW PRODUCTS

COMPONENT PARTS



HIGH-OUTPUT AMPLIFIER

Longest dimension of this rugged, miniature rf amplifier is only 5¾ in. Designed to increase signal power in the telemetering band, it delivers from 10 to 100 watts of r-f power with 2 watts of drive and can be used with most fm transmitters. Features include exceptional reliability in adverse environments of shock, vibration, and temperature, and a self-contained cooling system. According



HIPERNAS II

A new concept in advanced INERTIAL NAVIGATION SYSTEMS

Bell has outstanding opportunities for experienced engineers and scientists in the following areas:

- Inertial navigation system analysis and design
- Design and evaluation of gyros and accelerometers
- Airborne digital computer application
- Inertial test equipment development and design
- Transistorizing of analogue and pulse circuitry
- Advanced design and packaging

Assignments embrace a high level of design and development problems. Learn about the personal opportunities and unexcelled benefits now available to you on this challenging program. Send resume of your qualifications to: Supervisor of Engineering Employment, Dept. F-55, BELL AIRCRAFT CORPORATION, P. O. Box One, Buffalo 5, New York.

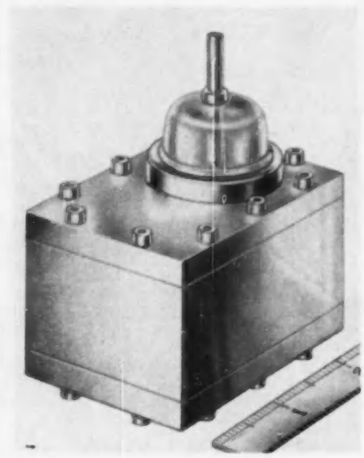
Niagara Frontier Division

BELL Aircraft CORP.

NEW PRODUCTS

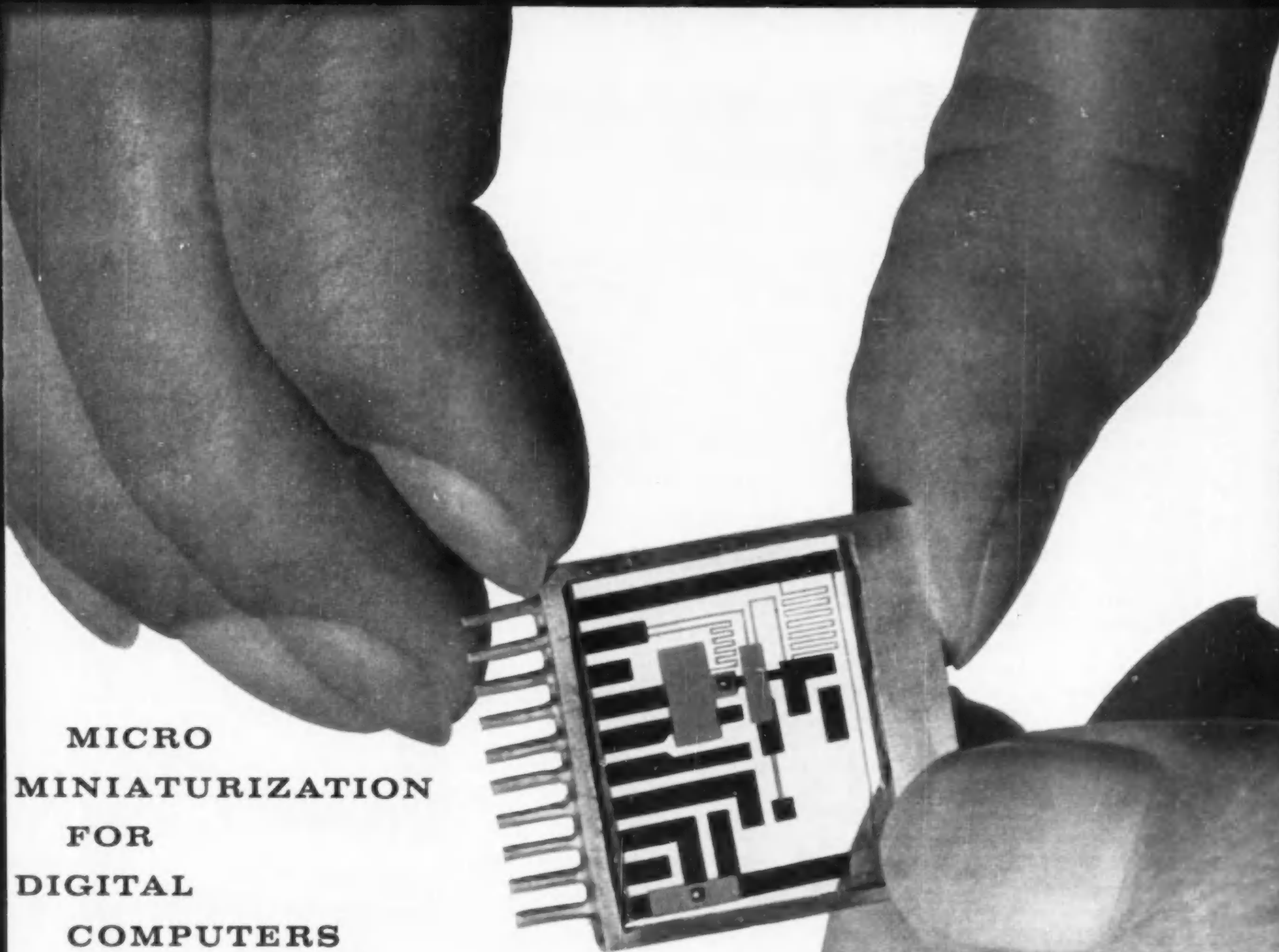
to the manufacturer, the tiny high-output unit meets the rigid environmental requirements of missile-borne instrumentation systems.—Rheem Mfg. Co., Rivera, Calif.

Circle No. 244 on reply card



DETECTS 10^{-16} AMPERE

The Vibrating Capacitor, a low-drift vibrating reed capacitance modulator,



NEW PRODUCTS

permits current measurements as low as 10^{-16} amp. A vibrating reed operated by a 500-cps driver coil forms one plate of a capacitor and a stationary anvil the other. With the unknown charge across it, the capacitance produces an alternating voltage proportional to the charge. This voltage may then be amplified by a stable ac amplifier. Drift due to self-charge or contact potential never exceeds plus or minus 0.2 mv per day noncumulative. This feature makes it suitable for process control applications requiring stable performance over long periods without recalibration.—Stevens-Arnold Inc., Boston, Mass.

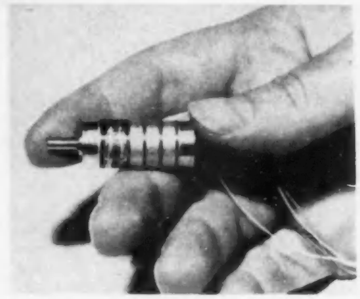
Circle No. 245 on reply card

JUMBO NIXIE

This new Jumbo Nixie type BD-307 digital indicator tube measures 3 in. in diam and is designed for visual presentation at viewing distances of over 150 ft. The new tube contains the numbers 0 through 9 and a common anode for circuit simplicity.—Burroughs Corp., Plainfield, N. J.

Circle No. 246 on reply card

NEW PRODUCTS



LESS THAN 1 OUNCE

This tiny 400-cycle servomotor, in BuORD size 5, weighs only 0.85 oz and is said to be shorter than any other presently available in its diameter. The standard motor 5S1-3 operates at 26 volts fixed phase, 40 volts center-tapped control phase, and draws 2 watts per phase input power. The 40-volt center-tapped control winding suits the unit for use with transistorized amplifiers.

Characteristics:

No-load speed: 11,000 rpm
Acceleration: 42,000 rad/sec².
Starting voltage: 0.6 volt, maximum
Stall torque: 0.1 oz-in., minimum
Power output: 0.3 watts at 6,000 rpm
Operating temperature: minus 55 to 85 deg C

–Mechatrol Div., Servomechanisms, Inc., Westbury, N. Y.

Circle No. 247 on reply card

PLUS . . .

(248) **Taber Instrument Corp.**, North Tonawanda, N. Y., has developed a new **drive for electrohydraulic servovalves**, consisting of a 150-mw power amplifier coupled to a solid-state phase-sensitive demodulator. . . . (249) A new double diffused **silicon transistor**, for use in military applications, was recently announced by the **Radio Div. of Western Electric Co.**, New York. . . . (250) **Cadillac Gage Co.**, Costa Mesa, Calif., has a new lightweight **torque motor** that can produce a mid-position force of 5 lb at 28 ma coil current. . . . (251) The Type 85-A precision **voltage divider**, consisting of two switch-controlled decades of high-accuracy fixed resistors together with a precision wire-wound potentiometer for continuous interpolation, is available from **Rinco, Inc.**, Portland, Ore. . . . (252) Developed by **Transitron Electronic Corp.**, Wakefield, Mass., the TM155 **silicon rectifier** features a 1,500-volt, 400-ma rating at a case temperature of 150 deg C.

Circle No. 248, 249, 250, 251 or 252 on reply card

GET

more information about

1. Advertised products
2. New product items
3. Catalogs and bulletins

All advertisements, new products and literature items are numbered for your convenience.

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL
First Class Permit No. 64, (Sec. P. L. & R.) New York, N. Y.

Reader Service Department 1

CONTROL ENGINEERING
330 West 42nd Street
New York 36, N. Y.

One of these handy prepaid post cards will bring you detailed information

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL
First Class Permit No. 64, (Sec. P. L. & R.) New York, N. Y.

Reader Service Department 1

CONTROL ENGINEERING
330 West 42nd Street
New York 36, N. Y.

HOW TO USE THESE CARDS:

1. Find the key number on item of interest
2. Circle this number on one of the cards
3. Mail card immediately

INSTRUCTIONS

Use these reader service cards to get more information on advertised products, new product items or catalogs and bulletins appearing in Control Engineering

IMPORTANT: Circle key numbers below and mail before February 1, 1959

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

Name ______ Title ______

Company ______

Address ______ City ______ Zone ______ State ______

IMPORTANT: Circle key numbers below and mail before February 1, 1959

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

Name ______ Title ______

Company ______

Address ______ City ______ Zone ______ State ______

1.

Circle number on card that coincides with key number listed at bottom or adjacent to item of interest.

2.

Fill in your name, title, company and address.

3.

Mail card immediately.

New! Miniaturized!

Kellogg Type "L" Relay

TYPE "L" RELAY FACTS

	FORM A	FORM B	FORM C	FORM D			REMARKS
CONTACT FORMS	(MAKE)	(BREAK)	(BREAK-MAKE)	(MAKE BEFORE BREAK)			13 SPRINGS MAX. PER STACK. ONE FORM D MAX. PER STACK.
CONTACT RATING (NON-INDUCTIVE)	TWIN CONTACTS			SINGLE CONTACTS			RATINGS PERTAIN TO CURRENT CARRYING CAPACITY UNDER NORMAL CONDITIONS. SPECIAL APPLICATIONS USUALLY REQUIRE ENVIRONMENTAL TESTING
	PALLADIUM	GOLD	SILVER	PALLADIUM	TUNGSTEN	SILVER	
	.062" x .020"	.062" x .020"	.062" x .020"	.093" x .031"	.125" x .050"	.125" x .050"	
	4 Amps. 150 Watts	1 Amp. 150 Watts	2 Amps. 100 Watts	4 Amps. 450 Watts	3 Amps. 450 Watts	4 Amps. 450 Watts	
TIMING (IN MILLI-SECONDS)	STANDARD COILS			SLUG COILS			TIMING VALUES ARE SUBJECT TO FURTHER LIMITATIONS DEPENDING UPPON CONTACT ARRANGEMENT AND APPLIED VOLTAGE
	OPERATE RANGE 3-30	RELEASE RANGE 4-20		OPERATE RANGE 20-60	RELEASE RANGE 30-100		
MISC.	COIL RESISTANCE			WEIGHT	RESIDUALS		
	SINGLE WOUND UP TO 20,000 OHMS	DOUBLE WOUND UP TO 6500 OHMS EACH WINDING		APPROX. 2¼ OZ.	AVAILABLE WITH SCREW OR FIXED TYPE RESIDUALS		

"Compact, lightweight, extremely versatile, *reliable*" . . . these are some of the comments of engineers who have tested Kellogg's new type "L" relay. It is a sturdy re-engineered version of the model used for years in telephone offices around the world. Now, its many new features make it particularly adaptable to industrial applications including computer systems, two-way radio and automation devices.

Efficient design gives the Kellogg type "L" more operating force than relays of comparable size. This means greater sensitivity, gram pressure and more springs per pileup. In addition, the new relay features:

- **rear mounting,** for ease of wiring
- **wide variety of coils** for any circuit requirements; single or double wound
- **bifurcated stationary springs** for independent contact action and high reliability; (single contacts also available)
- **heavy duty bronze** yoke and stainless steel bearing pin insure long life and stable adjustment
- **single or double** arm type armatures available
- **hermetically sealed** models, if desired
- **operating speed:** minimum of 1 to 2 milliseconds
- **contact points:** gold, silver, palladium, tungsten; other materials available
- **residual:** adjustable
- **time delay:** heel-end slugs and armature-end slugs for release time delay and operate time delay, respectively
- **terminals:** slotted
- **weight:** Net, 2¼ oz.
- **dimensions:** 2-1/4" L x 1-1/8" W, ranging in height from 17/32" to 1-1/16" (max.)
- **operating voltages:** up to 220 V.D.C.

Behind the superior reliability and design of Kellogg's type "L" relay are more than 60 years of experience as a leading producer of telephone equipment. And as the communications division of International Telephone and Telegraph Corporation, Kellogg has the research talent of 3500 engineers and technicians at its disposal.

Inquiries are invited. Send for a free catalog on relays and other components manufactured by Kellogg.

Kellogg Switchboard and Supply Company, 6650 South Cicero Avenue, Chicago 38, Illinois. Division of International Telephone and Telegraph Corporation.

KELLOGG
CHICAGO, ILLINOIS
Communications Division of ITT

Manufacturers of: Relays • Hermetically sealed relays • Switches • Solenoids

BULLETINS AND CATALOGS

(300) RELAY LINE. Magnecraft Electric Co. Catalog 159, 20 pp. Follows some general information on coil and contact ratings with descriptions, specifications, and illustrations covering standard, miniature, and subminiature relays of all types.

(301) A SAMPLING PROBLEM. Beckman/Scientific & Process Instruments Div. Application Data Sheet IR-88-MI, 6 pp. Shows how the development of microsampling accessories and techniques have made infrared spectroscopy a versatile analytical tool for the identification and analysis of minute samples of solids, liquids, and gases.

(302) PRESSURE SWITCHES. Century Electronics & Instruments, Inc. Catalog CEI-602, 28 pp. First few pages review general characteristics and features of Century's gas and liquid handling pressure switches. Photos, specs, and dimension drawings on individual types account for another 18 pages. Other data cover enclosures, contact ratings, and pressure-switch nomenclature.

(303) ACCURATE STEAM METER. B-I-F Industries, Inc. Bulletin 400-P25, 8 pp. Describes the principal features and typical specifications of the Shuntflo Model SMDH, a flowmeter designed for one to one and a half steam lines. Photos illustrate a typical installation as well as accessory equipment. Table shows meter capacities for various pressures and orifice sizes.

(304) MOTOR CONTROLS. Furnas Electric Co. Catalog 5800, 56 pp. Simplifies selection of electric motor control equipment. Special "quick selector" tables give horsepower, motor speed, heater size, and current ratings, and enclosure data.

(305) SYNCHRO TESTING. Theta Instrument Corp. Technical Bulletin, 15 pp. Describes the operation and application of three synchro and three resolver bridges. Detailed descriptions cover important application factors such as loading characteristics, voltage characteristics, quadrature rejection, measurement intervals, temperature tests, etc.

(306) PANEL INSTRUMENTS. General Electric Co. Bulletin GEA-6678, 6 pp. Text, pictures and tables describe GE's new line of small panel instruments, both dc and ac. Cut-away view clearly shows the self-shielding feature of the dc instruments. Other data covers ratings, dimensions, sizes, and panel drilling plans.

(307) DESIGN DATA. Induction Motors of California. Two reference data sheets. Cover general mechanical and electrical specifications for synchros and resolvers, including such components as torque receivers, torque transmitters, control transformers, linear transformers, and resolver transmitters. Table show physical size, configuration, and materials.

(308) TRANSISTORIZED SUPPLIES. Sorensen & Co., Inc. Data sheet, 2 pp. Highlights include a list of specifications and a summary of features common to a complete line of transistorized low-voltage high-current dc supplies, with outputs of 6, 12, or 28 volts, at 15 or 30 watts.

(309) LIGHT CONTROL. Electronics Corp. of America. Bulletin PA 569, 4 pp. Contains some interesting descriptive data on Photoswitch Light Control, a new automatic on-off control for any lighting system whose operation is keyed to outdoor light conditions.

(310) SERVOVALVES. Borg-Warner Corp. Bulletin No. 5801, 4 pp. Provides basic design and performance data on the new line of Pesco high-fidelity servovalves. Included are detailed descriptions of valve operation and of components.

(311) GAS ANALYZER. Beckman/Process Instruments Div. Bulletin 0-4114, 2 pp. Covers operation and specifications on the Model 80 Oxygen Trace Analyzer, a dual range instrument which continuously measures gas samples for quantities of oxygen as small as 0 to 5 ppm.

(312) PRECISION SWITCHES. The W. L. Maxson Corp. Bulletin 858A, 4 pp. Presents photos, dimension drawings, circuit arrangements, force and movement specs, and electrical ratings in dealing with the Unimax Type A snap-acting switches. Also shows standard and auxiliary actuators, and terminal types available.

(313) FLOWMETER. B-I-F Industries, Inc. Bulletin 115-LIB, 4 pp. Offers dimension and capacity tables for a complete line of Dall Tube differential producers. Installation diagrams and a pressure-recovery performance chart also included.

(314) ANALOG COMPUTER. Mid-Century Instrumatic Corp. Folder, 4 pp. Condenses some 14 pages of specifications and description on the MC-5800 Master Precision Analog Computer, clearly illustrates a unique design feature that permits unobstructed access during maintenance.

(315) NEW GEAR PUMP. Borg-Warner Corp. Bulletin, 4 pp. Three-color schematic drawings illustrate the operation of a new variable-displacement gear pump that will accommodate pressures to 3,000 psi, temperatures to 500 deg F, and speeds to 24,000 rpm. Bulletin also lists advantages and suggests applications.

(316) OIL-FILLED POTENTIOMETERS. Helipot Div. of Beckman Instruments, Inc. Data Sheet 1482, 7 pp. Summarizes technical data on three liquid-filled potentiometers now in production. Graphs indicate maximum input power level.

(317) LOGIC PACKAGE. Sprague Electric Co. Engineering Bulletin 6712, 4 pp. Uses nine circuit diagrams to illustrate application of the company's Type 200C9 Multiple Logic Package for computer design work. Discusses input load and operation for each circuit shown.

(318) FOR COUNT CONTROL. Computer-Measurements Corp. Technical Bulletin 320, 4 pp. Deals with a line of dual preset counter-controllers designed for coil winding, motor-speed control, shearing to length, batching, packaging, stacking by number, variable pulse interval generation, and process programming.

(319) RECTIFIER POWER UNITS. Syntron Co. Catalog, 10 pp. Illustrated booklet contains complete descriptions, data, and specifications on the company's line of selenium and silicon rectifier power units. Single-phase, three-phase, and special low-voltage units are covered.

(320) CLUTCHES & BRAKES. Eaton

BULLETINS AND CATALOGS

Mfg. Co. Bulletin RSF-1, 8 pp. Announces the addition of three new models to the maker's line of Dyna-torQ magnetic friction clutches and brakes. Circuit diagram, photo, and text introduce a simple plug-in type control that provides continuous dc for actuating these units.

(321) ON pH TECHNIQUES. Beckman/Scientific & Process Instruments Div. Application Data Sheet pH-85-MI, 5 pp. Discusses proper care of pH electrodes and techniques for making accurate pH measurements in troublesome samples such as soils, emulsions, suspensions, and oils.

(322) PULSE GENERATORS. Electro-Pulse, Inc. Short Form Catalog 1958-59, 4 pp. Tables show principal characteristics of a complete line of pulse generating and counting equipment, as well as block units for special-purpose pulse instruments.

(323) X-Y RECORDER. Electronic Associates, Inc. Bulletin No. AP-810, 4 pp. Reveals overall appearance of the Model 1100E Variplotter in full color with close-ups of the control surfaces. Technical specifications and design features are described completely.

(324) MANOMETER DATA. King Engineering Corp. Catalog 2008, 24 pp. Introduction discusses the operation and accuracy of U-tube, well-type, and inclined-tube manometers. Section on selection criteria assists in determining the best combination of manometer type, range, scale, indicating liquid, mounting, and accessories for specific applications.

(325) PRESSURE TESTING. Intercontinental Dynamics Corp. Bulletin, 4 pp. Describes a portable vacuum and pressure instrument test set and points out those aircraft panel instruments and gages that can be tested with the unit.

(326) NEW SERVOVALVE. Eastern Industries, Inc. Bulletin, 6 pp. Reports on a new pulse-length modulated servovalve developed for use in electrohydraulic control systems. Theory and merits of this mode of operation are discussed, and data from a typical valve presented.

(327) SPECIAL CERAMICS. Coors Porcelain Co. Bulletin No. 858. Short form catalog illustrates the company's production facilities and lists mechanical and electrical properties of their high-alumina ceramics. Also discusses forming techniques.

(328) COMPANY FACILITIES. Model Engineering & Mfg., Inc. Bulletin, 8 pp. Introduces this outfit's newly adopted symbol, MEMCOR, and provides information on its four major divisions: Electronics, Precision Mechanical, Courter Products, and Tru-Ohm Resistor Products.

(329) FORMULA CONTROL. Richardson Scale Co. Bulletin NP-1, 2 pp. Explains how a new Boss Board control, used with Richardson "Select-O-Weigh" systems, completes the automation of batching and mixing operations. Also tells how the unit guards private formulas, maintains continuous production.

(330) T'COUPLE ASSEMBLIES. Conax

Corp. Catalog 1885, 36 pp. Fully indexed catalog covers a complete line of thermocouple assemblies and pressure sealing glands, introducing many new additions that have appeared since the last general catalog was issued.

(331) MOISTURE METERING. Schlumburger Well Surveying Corp. Material Study Report No. 4.58. Details a method for determining moisture in silica gel, using the Model 104 Nuclear Magnetic Resonance Analyzer. Report also discusses sample preparation and shows a typical calibration curve.

(332) TINY TRANSFORMERS. Microtran Co., Inc. Catalog, 24 pp. Describes a complete line of miniature, subminiature, transistor, MIL-T-27A, and industrial transformers available from distributor stock. New transistor transformers include dc to dc converters, silicon rectifier-power units, and driver, input, output, and chopper transformers.

(333) POLARIZED RELAYS. The Hart Mfg. Co. Bulletin P78, Catalog sheet, 2 pp. Introduces the manufacturer's Series P polarized relays for electronic and communications applications requiring fast action with freedom from bounce. They have high sensitivity and good stability.

(334) WEIGHING SYSTEM. Morehouse Machine Co. Bulletin 169, 4 pp. Covers advantages, construction, operation, and specifications of a completely transistorized, battery-powered calibrating and weighing system checking calibration of load cells, torque-measuring dynamometers, thrust stands, testing machines, and other force measurement equipment.

(335) POWER AT 47 TO 6,000 CPS. Empire Devices Products Corp. Bulletin VP-858, 2 pp. Illustrates and describes two new variable-frequency power supplies, lists a number of typical applications. Explains such features as the self-contained Wein bridge oscillator, multiple feedback loops, and provision for external drive.

(336) NUMERICAL CONTROL. Marac Machinery Corp. Catalog, 12 pp. Discusses what is believed to be the first machine tool in the world on which numerical control is offered as standard (not optional) equipment—a boring and milling machine, combining production-room ruggedness with near-jig-borer accuracy.

(337) TANK GAGES. Jerguson Gage & Valve Co. Data Unit No. 330, 2 pp. Briefly covers the features, construction details, and specifications of the Jerguson reflex and transparent welding pad gages, units made to weld right onto a tank, vessel, or liquid containing structure.

(338) ELECTROMECHANICAL COMPONENTS. Hoover Electric Co. Recently completed catalog features drawings and performance curves of over 120 electric motors, linear actuators, rotary actuators, solenoids, power units, screw-jacks, gear boxes and test equipment.

(339) VOLTAGE REGULATORS. The Superior Electric Co. Data Sheet SE-L3584, 2 pp. Tells how the Stabiline automatic voltage regulator, type EMT25136U, meets the need for a reliable automatic device to provide a gradual power run-up and constant regulated voltage for high-priced complex vacuum tubes in sensitive equipment.

WHAT'S NEW

(Continued from page 42)

Station, Wallops Island, Va.; or the Plum Brook Research Reactor Facility, Sandusky, Ohio.

The 28 committees and subcommittees of NACA have been reconstituted as advisory committees to the NASA and will keep this status until the end of the year, in order to complete their work. NASA has moved into the Washington, D. C., headquarters of the 43-year-old committee. From here, it will direct a staff of more than 8,000 scientists, engineers, technicians, and others, and oversee laboratory facilities valued at more than $300 million.

Control Data Corp. Has a Bad Year

Pleading "substantial getting-started costs", Control Data Corp. of Minneapolis, Minn., reports a net loss in its first year of operation of $114,716, and a gross profit, after subtracting the costs of making sales ($598,554) from the sales themselves ($625,756), of $27,202. Selling, administrative, and general expenses totaled $144,810, leaving an operating loss of $117,608. Further deductions brought this down to the $114,716.

Backlog was put at $2 million, assets at $1,223,311. The payroll was said to have jumped from four, when the company opened for business last year (CtE, Nov. '57, p. 182), to 260.

Most of these year-end figures come from Control Data itself, but some of them come from a report in the weekly *Electronics News*, which has a correspondent in Minneapolis. The newspaper explains that Sperry Rand Corp. has a suit in progress against Control Data, charging it with using trade secrets, then quotes William Norris, president of the firm, as saying, "There is still considerable doubt as to the nature of the Sperry Rand complaints. No date has been set for trial of the case, but it is anticipated that trial will be held some time in winter of 1958-1959."

Norris developed Control Data from his own Electronic Associates, which in turn seems to have had a connection with Remington Rand Univac.

Now It's: Hunt Valve Co., Computer Equipment Corp.

Two companies in the control field have changed their names to more

closely identify them with the products manufactured. The companies are: C. B. Hunt & Sons, Inc., which becomes Hunt Valve Co., and Digitron, Inc., which in the future will be known as Computer-Equipment Corp.

More Than 1,200 Suppliers for Atlas; Most Are Small

Several control companies have issued news releases lately noting the fact that they are among key suppliers in the Atlas ICBM program under way at the Convair-Astronautics Div. of General Dynamics Corp. It develops that these disclosures are all part of an Astronautics plan to encourage increased tie-in advertising and publicity for the Atlas program, and that the number of suppliers given the green light to identify themselves is well over 1,200.

Advertising benefits from the disclosures will also accrue to these suppliers, of course, most of whom are small firms. Some figures given by Astronautics about them: they are located in 344 towns in 36 states, have on the average less than 500 employees, and do an Atlas business totaling about $90 million.

Astronautics won't say whether it will reissue the supplier list at some future date. For one thing, the results of the present one are not in yet, and for another, it takes a great deal of work to put one out. If things go well, however, says Astronautics, it may issue amended lists at judicious intervals.

A sample of the names on the list: Rocketdyne, Aerojet General, Goodyear Aircraft, Filtron Co., Kin Tel, Litton Industries, Epson, and Hill Electronic Engineering & Mfg. Co. of Mechanicsburg, Pa.

New Companies in the Field

Shockley Transistor Corp., a new subsidiary of Beckman Instruments, Inc., actually a reorganization of the company's Shockley Semiconductor Laboratory—in Palo Alto, Calif. The new corporation will expand Beckman's development and manufacture of specialized semiconductor components for electronic instruments, communication equipment, and control systems beyond the point envisaged when the Shockley lab was organized more than two years ago (CtE, May '56, p. 30). Two strides

GULTON SHOCK AND VIBRATION DATA FILE

How to avoid false test results due to "ground loop" voltages

With the increasing need for greater accuracy in shock and vibration measurement, extreme care should be taken to avoid the introduction of spurious voltages.

Circulating ground currents, generated by electrical devices external to the measuring system, generate voltages that can lead to completely false results.

GROUNDING USUALLY AT FAULT

Ground loops may come from various extraneous sources.

Figure 1 shows how circulating ground currents in a structure can induce electrical voltages in a typical shock and vibration measuring system. In this example, the accelerometer, amplifier and data handling or recording equipment are placed at three separate locations. Each instrument has its electrical circuitry grounded to the housing, and each housing is connected electrically to the structure at points A, B and C.

Voltages E, produced in the structure by the circulating currents, are introduced into the measuring system between points A&B and B&C.

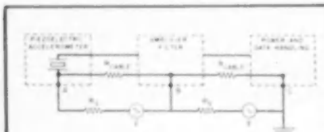


Figure 1: How ground loops are induced

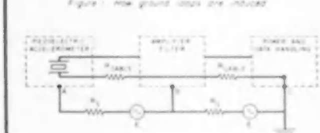


Figure 2: Local ungrounding isolates ground loops

SOLUTION TO THE PROBLEM

First, all electrical apparatus capable of generating currents should be ungrounded and a *single heavy point ground* employed.

Anthony W. Orlacchio
Chief Engineer
Gulton Instrumentation Division

Second, all measuring instruments should be ungrounded at local points and the entire system grounded at the single point.

Figure 2 illustrates a recommended technique for ungrounding the system described in Figure 1. By removing the internal circuit grounds from structural points A and B, ground loop voltages are isolated from the measuring system.

UNGROUNDED INSTRUMENTS THE ANSWER

Today, a new series of Gulton accelerometers and associated electronic equipment is available with *internal ungrounding*.

Accelerometers contain sensitive seismic elements insulated from mounting studs by rugged ceramic insulation.

Filter and amplifier circuitry, as well as connectors, are electrically insulated from the housing which can then "float" at the local ground potential of the mount with no effect upon the measuring signal.

SEND FOR TECHNICAL DATA

For more complete information on Gulton ungrounded instrumentation systems, contact your local Gulton representative or write us direct.

FREE TECHNICAL SERVICE OFFERED BY GULTON

A Gulton Instrumentation Engineer will gladly call at your request to help you with instrumentation problems. You are invited to put his extensive experience in shock and vibration measurement to work for you.

GULTON INSTRUMENTATION DIVISION

Gulton Industries, Inc.

Metuchen, New Jersey

CIRCLE 110 ON READER-SERVICE CARD

contemplated: a ten-fold increase in the production of the Shockley four-layer transistor diode, an electronic switch capable of replacing five related components, and a greater emphasis on semiconductor devices that require advanced theoretical understanding of semiconductor properties. William Shockley will be president of the new corporation, and Maurice C. Hanafin, formerly general manager of Beckman's Spinco Div., will be vice-president and general manager.

Westinghouse International Atomic Power Co., organized as a subsidiary of Westinghouse Electric International Co., to serve nuclear power needs in Europe–in Geneva, Switzerland. Chairman of the board is Kenneth D. Nichols, atomic consultant to Westinghouse Electric Corp., and president is Raymond Giguet, formerly associate director general of Electricite de France. Principal countries to be served are France, Italy, Belgium, The Netherlands, Luxembourg, and West Germany.

Connecticut Instrument Corp., founded by two former Perkin-Elmer men, Charles W. Warren and Paul A. Wilks Jr.–in Wilton, Conn. The new company will develop and produce research and control instruments, and provide a service in ultrasonic impact grinding. Warren was president of Warren Electronics Corp. before that company was bought by Perkin-Elmer; after the purchase he assisted in integrating the new products into P-E's line. Wilks' most recent position with P-E was director of marketing.

Scans Associates, Inc., to engineer and manufacture hydraulic, pneumatic, mechanical, and electrical equipment –in Livonia, Mich. President Vernon G. Converse III and fellow officers Stanley R. Anderson, Robert A. Newhouse, Lee J. Seymour, and Samuel F. Sgriccia were all formerly with George L. Nankervis Co.

Space Electronics Corp., formed by two Ramo-Wooldridge men to develop ground and airborne electronic equipment for missiles and space vehicles–in Glendale, Calif. J. C. Fletcher, formerly director of R-W's Electronics Laboratory, is president of SEC, and Frank W. Lehan, formerly associate director, is vice-president. Other officers include W. R. Hughes, formerly director of test support in R-W's Space Technology Laboratories, whose title is head of engineering, and Ray W. Sanders, most recently section director of guided missiles for Gilfillian Brothers, Inc., who is a senior member of SEC's technical staff.

IMPORTANT MOVES BY KEY PEOPLE

Chief Engineers Advance in Douglas Realignment

Douglas Aircraft Co. has realigned the functions of its Engineering Div. into three major fields and has appointed a director for each. The directors are: Elmer P. Wheaton, formerly chief missiles engineer at Santa Monica, Calif., assigned to missiles and space engineering; Edward H. Heinemann, formerly chief engineer for the El Segundo (Calif.) Div., assigned to combat aircraft systems; and Edward F. Burton, formerly chief engineer for the Santa Monica Div., assigned to transport aircraft systems.

In each case, assistant chief engineers replace their superiors in their respective divisions. This means that R. L. Johnson becomes chief engineer of missiles and space systems, L. J. Devlin moves up at El Segundo, and Schuyler Kleinhans advances at Santa Monica.

In the Charlotte (N. C.) Div., which manufactures missiles for the Army, A. D. Jamtaas has been promoted from engineering manager to chief engineer. All missile and space activities at Douglas, incidentally, are now under the unified control of one director, who functions at the general-office level.

Wheaton joined Douglas as a physicist in 1934. In 1941, he carried out development of a guided bomb that could find its target by means of a television eye in its nose. He became chief missiles engineer at the Santa Monica Div. in 1955. Heinemann came to Douglas in 1926, has been chief engineer at El Segundo since 1936. Burton has worked on every DC (Douglas Commercial) model since joining the company in 1924. He became chief engineer at Santa Monica in 1940.

Johnston Next in Line as Frost Takes ISA Helm

Things took their natural course at the ISA annual conference and exhibit in Philadelphia last September, when Henry C. Frost, assistant chief engineer of Corn Products Refining Co., Chicago, moved from president-elect and secretary into the presidency, succeeding Robert J. Jeffries, president of Data-Control Systems, Inc. A

report on the conference appears in this issue, page 18.

Other new ISA officers are: John Johnston Jr., supervisor of du Pont's Engineering Service Div.'s consultation group for instrumentation development and a CtE consulting editor, elected to succeed Frost in the springboard position; Glen C. Gallagher, principal instrument engineer for Fluor Corp., Ltd., of Los Angeles, vice-president for the Standards & Practices Dept.; Thomas C. Wherry, assistant branch manager of Phillips Petroleum's Instrument & Equipment Laboratory and a CtE author (March, page 115), vice-president of the Technical Dept.; and Howard W. Hudson, vice-president of manufacturing for Panellit, Inc., reelected treasurer.

Other Important Moves

As the new assistant chief engineer of Ling Electronics, Inc., **Ray L. Reid** will take direction of an R&D program involving vibration tests for system components and will act as technical consultant to Ling subsidiaries. Reid was formerly specialist in electrical and vibration testing at North American Aviation. (For a major story about Ling see page 40.)

Early T. Andes, formerly chief engineer for the Western Div. of Cramer Controls Corp., has been appointed project engineer for Task Corp. of Anaheim, Calif. He will specialize in the design of dc and ac motors, generators, and solenoids.

Control Data Corp. (see page 168) has appointed the following men to its computer engineering staff: **James E. Thornton,** named senior electrical engineer in charge of advanced computer circuit design; **Carl E. Koehler,** named systems logical designer; **Dean M. Roush,** named to the Mechanical Engineering Group; and **James D. Harris,** named senior administrative assistant. All, in Control Data's still rather mysterious tradition, are former Remington-Rand Univac men.

R. W. Martin, the former president of Physical Measurements Corp., a subsidiary of Technology Instruments Corp., has joined Burton Mfg. Co. of Santa Monica, Calif., as director of engineering and sales. Before taking Technology Instrument's helm, he was its division manager and director of engineering. He has also been with Summers Gyroscope Co. and G. M. Giannini & Co., Inc.

Kenneth W. Meytrott has been elected chairman of the board of Ettco Tool & Machine Co., Inc., and **Edward G. Maylinger** has been elected president. They succeed the late **Melvin H. Emrick** CtE, Oct., p. 54), who had held the two positions.

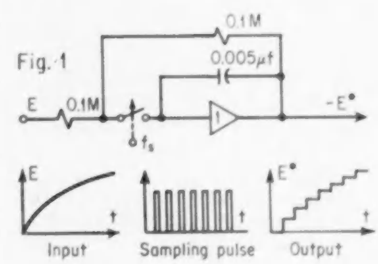
ABSTRACTS

Analog Simulation Extended

From "Analog Computer Study of Sampled-Data Systems" by H. Chestnut, A. Dabul, and D. Leiby, all of GE. AIEE Transactions Paper No. 58-1324, prepared for presentation in Pittsburg.

Recent studies of sampled-data systems have been based largely on frequency response methods, z-transform techniques, and various modifications of both. This paper describes a new technique for handling these systems on analog computing equipment. It indicates the performance of typical sampled-data systems for different values of system parameters and, where possible, correlates these results with those obtained by frequency domain and time domain approaches.

The new technique involves simulation of two new elements: the sampling switch and the holding circuit. In this study, a high-speed mercury-wetted relay provides the sampling function. One operational amplifier, connected with the relay as shown in Figure 1, simulates the zero-order



hold function. With the switch closed the amplifier operates with unity gain and a very small time constant; with the switch open, it serves as an open input integrator. Figures below the computer diagram show the input, pulse, and output waveforms.

With a sampling frequency below 5 cps, a 10-millisec pulse will require less than 5 percent of the sampling time. For the values of feedback resistance and capacitance shown in Figure 1, the amplifier time constant is 0.5 millisec. Under these conditions, amplifier output can be assumed to reach its final value while the switch is closed.

The relay driving signal, if not directly available from the computer installation, can be produced by using several operational amplifiers driven from a variable frequency sine-wave generator. Figure 2 shows the circuit arrangement and Figure 3 the evolution of the pulse train output. Note

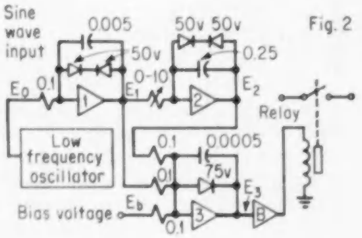


Fig. 2

how the introduction of bias voltage E_b shifts the origin so that the net voltage input to amplifier 3 becomes positive only during a portion of the

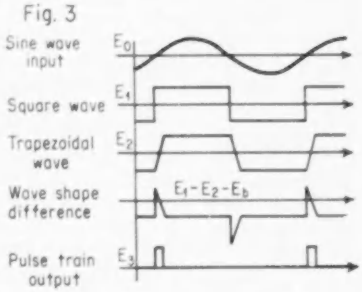


Fig. 3

positive pulse. With the limiting diode shown, output of this amplifier goes to full limiting voltage for any positive input and to zero for the rest of the input cycle. Amplifier B is simply a booster to operate the relay coil.

To illustrate an application, and to simplify comparison of analog computer results with those obtained from a mathematical model representation, the authors chose a simple second-order system. This is represented in a practical way by a simple position servo, consisting of an ideal amplifier, driving motor and gear train, and a position-to-voltage transducer for the feedback element. It is shown in Figure 4 (authors' Figure 5). Here amplifier

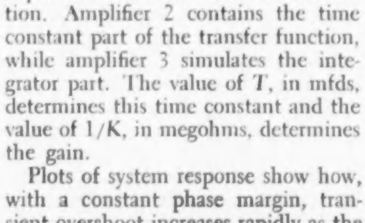


Fig. 4

1 performs the zero-order hold function. Amplifier 2 contains the time constant part of the transfer function, while amplifier 3 simulates the integrator part. The value of T, in mfds, determines this time constant and the value of $1/K$, in megohms, determines the gain.

Plots of system response show how, with a constant phase margin, transient overshoot increases rapidly as the dimensionless sampling frequency (or sampling frequency to crossover fre-

quency ratio) is reduced. From a large number of transient responses, a family of curves can be developed to serve as a useful design tool. Here the dimensionless sampling frequency is plotted as a reciprocal curve along the abscissa while the ordinate contains a linear plot of percent positive peak overshoot. Curves are then plotted for different values of linear system phase margin. These may then be used to predict the effect of sampling frequency on the performance of any linear second-order system having a given phase margin. They also permit the comparison of sampled-data and continuous systems by showing the phase margin required by each to produce the same transient performance.

Correlation of these results with those obtained by several analytical methods proved excellent in most cases. The computer simulation, however, did show a slightly lower minimum sampling frequency than did a detailed analysis.

Other applications of this analog computer method are to higher-order sampled-data systems and to systems with nonlinearities in the continuous portion. Here no limiting assumptions need be made concerning nonlinearity.

Remote Control Pays Off

From "An Integrated Electric Control System for Unattended Pumping Stations" by H. B. Rath, Leeds & Northrup Co. ISA paper presented at Philadelphia, Pa., Sept. 14-19, 1958.

Control of unattended pumping stations from a central dispatching center offers several economic advantages. It reduces operating costs by lowering the manpower requirement, reduces the initial installation costs by eliminating the need for housing personnel, and boosts efficiency through the use of automatic controls.

At the station, an automatic electric control system, requiring no air supply, operates to maintain maximum output without exceeding physical limitations of the equipment. Supervisory controls at the dispatching center permit starting and stopping the station pumps as well as changing setpoints. Going a step further, the station can be arranged to come on the line automatically whenever an economical contribution to the operation will result. Telemetering equipment, also part of the system, provides the dispatch center with actual station operating conditions.

NEW BOOKS

A Fresh Approach to Feedback

Feedback Control Systems. *Otto J. M. Smith, Professor of Electrical Engineering, University of California, Berkeley. 694 pp. Published by McGraw-Hill Book Co., Inc., New York, 1958.* $13.50.

While it is always a pleasure to find a book which presents both accepted practices and techniques and a vast array of original ideas and viewpoints, the pleasure is particularly poignant in the area of feedback control systems, where so many books have followed so unimaginatively the original path established by Brown and Campbell's memorable work of a decade ago. Above all, Mr. Smith's book is marked by the audacity with which he departs from this beaten path to present a continuing flow of novel attitudes toward control system design and unusual configurations or devices in feedback control systems. As a consequence, the book fills an important gap in the literature and should be a most valuable reference.

The avowed objective of the book, as expressed in the preface, is "to present a unified philosophy for the analysis and design of all types of feedback systems", with the hope "that the techniques presented here will become widely applied in sociological systems". While the reviewer personally doubts the likelihood of the fulfillment of this hope in the foreseeable future, the book does represent an important step toward presentation of this unified philosophy —with an emphasis strongly on an understanding of the fundamental aspects inherent in the use of feedback and the realization of desired system characteristics through a careful selection of system configuration, a full appreciation of the importance of the nature of the input signal, and a deep understanding of the interrelations among open-loop and closed-loop performance characteristics.

The book is divided into four parts: linear analysis, linear synthesis, steady-state nonlinear analysis, and nonlinear synthesis. Written at the level of the beginning graduate student already familiar with basic methods of linear system analysis, the text could also be used satisfactorily as a sequel to any of the numerous introductory servo texts.

The remarkably novel coverage of the book is best illustrated by listing several topics specifically covered here and not ordinarily discussed in other,

comparable texts. For example, in the second part, the author includes a brief discussion of 1) AGC systems, with analysis based on linearization in the vicinity of the operating point, 2) distributed parameter systems (including a detailed discussion of the posicast control of lightly damped systems, as described in earlier papers by the author), 3) multiloop systems, including those with model feedback intentionally introduced, and 4) parallel control systems involving both high-power and low-power transducers. The third part contains a detailed discussion of multilevel decision functions in the generalization of relay system analysis, and even includes a mention of multiplicative nonlinearities (although, through no fault of the author, very little is done with the topic analytically). The final section provides a lengthy discussion of predictor control of nonlinear systems, although little is said about the justification for the use of predictor control in such cases. The book concludes with a refreshing chapter on carrier systems, clearly describing the effects of modulated signals on the critical frequencies of the pertinent network transfer function.

While the reader familiar with the typical introductory books may occasionally become alarmed by the unconventional terminology of the author, such a minor difficulty is perhaps unavoidable when the author expands the breadth of viewpoint to the extent here, where conventional analysis techniques are presented in many cases as facets of more general approaches to the understanding of system behavior. The 30 or more problems included with each chapter and the bibliographies listing major references of interest are important aspects of the book, all too often omitted by other authors. This is an important contribution to works on analysis and synthesis of feedback control systems.

—John G. Truxal

On Using Static Switches

STATIC CONTROL APPLICATION MANUAL. *Prepared and published by GE's General Purpose Control Dept. 152 pp., illus. Available through the General Electric Co., Schenectady 5, N. Y.* $5.00.

Now in its third edition, this 8½ by 11 paperbound application manual discusses the fundamentals of static switching and tells the practicing engineer why, when, and where to use it in general-purpose applications.

WHAT'S AHEAD: MEETINGS

NOVEMBER

International Conference on Astronautics, sponsored by Southwest Research Institute and Air Force School of Aviation Medicine, San Antonio, Texas Nov. 10-13

Institute of Radio Engineers, Northeast Electronics Research and Engineering Meeting, Mechanics Hall, Boston, Mass. **Nov. 19-20**

Eleventh Annual Conference on Electrical Techniques in Medicine and Biology, sponsored by IRE, AIEE, and ISA, Nicollet Hotel, Minneapolis, Minn. Nov. 19-21

Electronic Computer Exhibition & Symposium, Olympia, London Nov. 28-Dec. 4

American Society of Mechanical Engineers, Annual Meeting, Statler Hotel, New York City Nov. 30-Dec. 5

DECEMBER

American Society of Mechanical Engineers, 23rd National Power Show, Coliseum, New York City Dec. 1-5

Third Electronic Industries Association Conference on Reliable Electrical Connections, Dallas, Texas Dec. 2-4

Eastern Joint Computer Conference; theme: Modern Computers–Objectives, Design and Application, Bellevue-Stratford Hotel, Philadelphia Dec. 3-5

American Institute of Chemical Engineers, Annual Meeting, Netherlands Plaza, Cincinnati, Ohio Dec. 7-10

JANUARY

Institute of Radio Engineers, Fifth National Symposium on Reliability and Quality Control, Bellevue-Stratford Hotel, Philadelphia Jan. 12-14

MARCH

Western Joint Computer Conference; theme: New Horizons with Computer Technology, Fairmont Hotel, San Francisco, Calif. Mar. 3-5

Institute of Radio Engineers, 1959 National Convention and Exposition Waldorf-Astoria Hotel and New York Coliseum, New York Mar. 23-26

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

First-Hand Report on Control Inside Russia, November 1958, 16 pp. A team of 14 U. S. control engineers representing the American Automatic Control Council reports on the status of automatic control in Russia. Each expert gives impressions of progress in his field of interest based on visits to Russian user plants and research facilities. 40 cents.

Electronic Process Control Systems, November 1958, 16 pp. A staff report on the hottest area in materials processing control. Besides giving complete data on the six commercially available electronic process control systems (four of them were first announced at the 1958 ISA show), the article discusses the common denominators of all such systems and points out why user, consultant, and maker are interested in electronics. 40 cents.

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What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources are listed. 20 cents.

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Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

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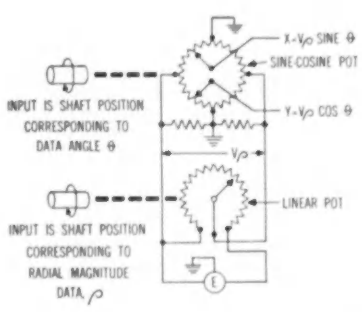

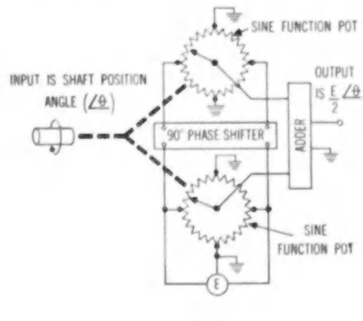

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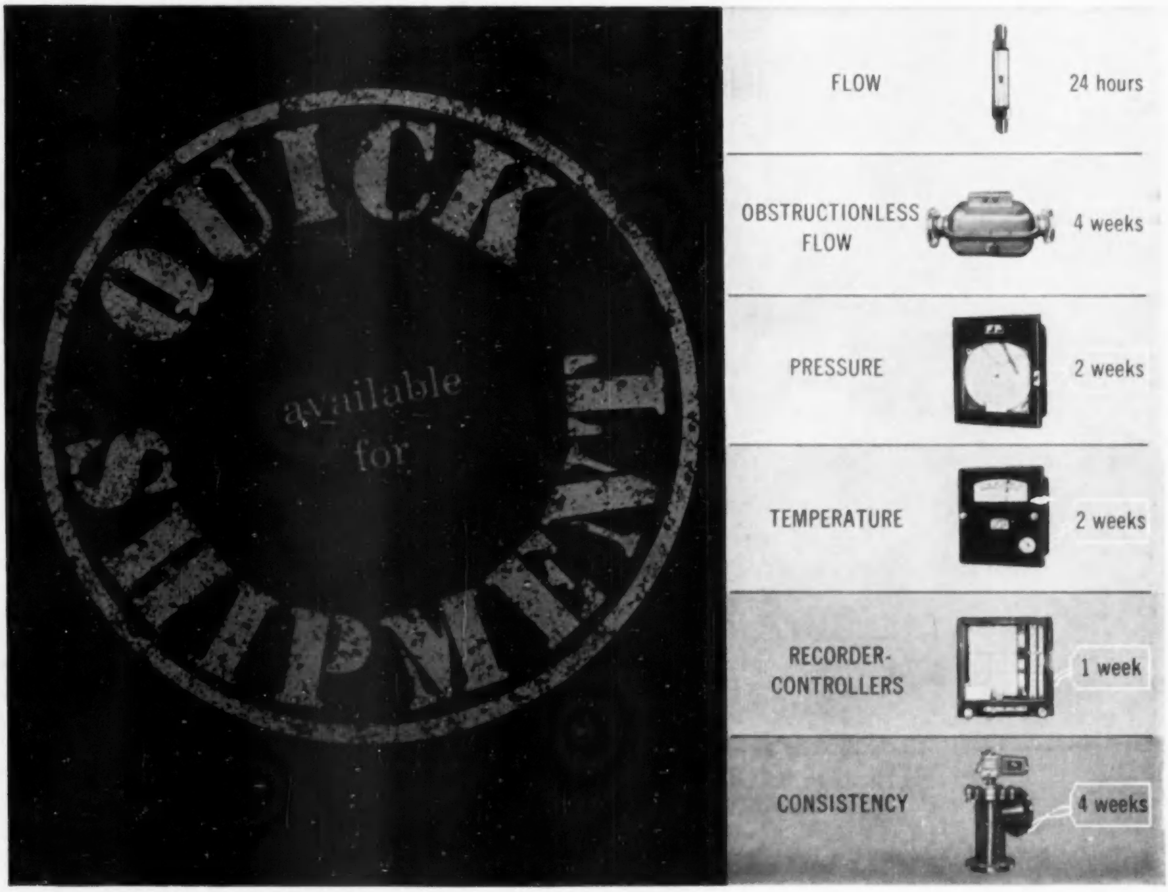

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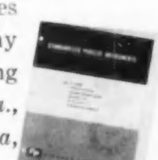

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